November 1990 A Cahners Publication

R&D®
Research & Development

FOLLOW-THROUGH
3M's formula for success
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Six hot areas: Ceramics to advanced composites

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A salute to France's high technology

Developing products like this nonwoven material earns 3M the Corporation of the Year Award

INTERNATIONAL MAGAZINE OF RESEARCH AND DEVELOPMENT

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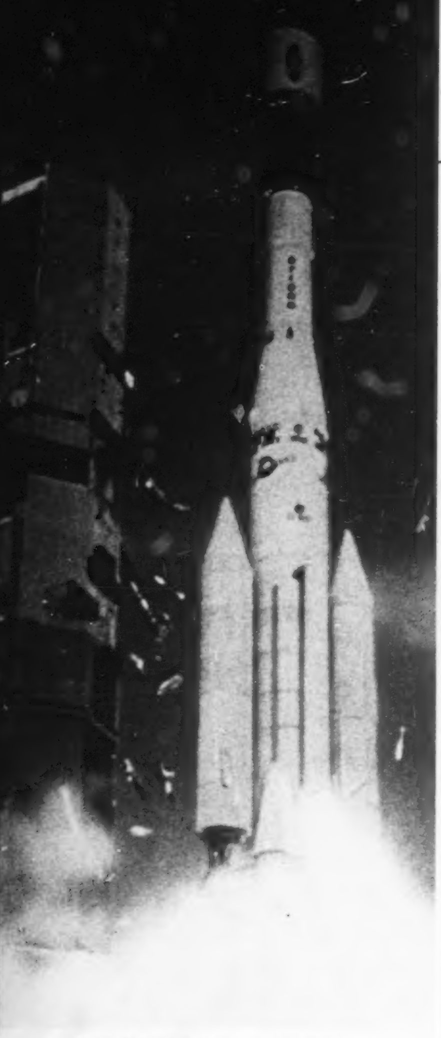
3M earned the Corporation of the Year award for its ability to "follow through" on new products, such as the nonwoven fabric shown in the photo. See story on page 46. Photo courtesy of 3M Corp.



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Globalize your R&D, says MIT's Thomas Lee

GLOBALIZATION OF R&D, production, investment, and technology is a positive trend for the U.S. and the rest of the world, says Thomas Lee, a professor of electrical engineering at Massachusetts Institute of Technology, Cambridge. Lee is committee chair and author of the National Academy of Engineering report "National Interests in an Age of Global Technology."

The current U.S. policy of placing a high priority on basic research and "mission-oriented" technologies neglects national vulnerabilities, according to the committee. A higher priority should be placed on adapting technology, regardless ot its origin, its report says.

The technical and economic vitality of any country, including the U.S., depends on how quickly and how effectively companies operating within its borders can exploit all the global resources and technical capabilities that are available in a global environment, says Lee.

Actions that he says the U.S. should take to exploit global technology include:

- supporting methods to adopt or adapt existing technologies, such as those in the National Science Foundation's Engineering Research Centers
- supporting generic technologies, such as total quality control, computer-aided design, and just-in-time production systems
- encouraging modernization of capital equipment in private industry
- hiring and training employees to have greater technical expertise in agencies responsible for domestic and international economic policy.

The report also lists emerging technologies and various countries' strengths in several industries, including aircraft engines, automotive, biotechnology, chemicals, semiconductors, and electrical equipment.

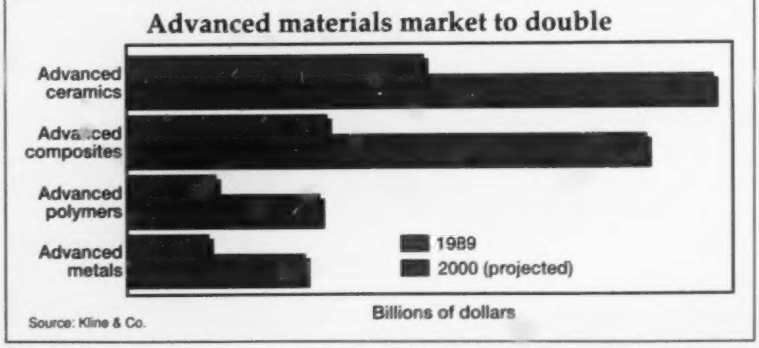
To get a copy of the report, call 202/334-3313. *—Tim Studt*

Boom times ahead for advanced materials

ELECTRONICS MANUFACTURERS will pay up to $1,000/lb for a high-performance circuit board," says Carl Eckert, vice president of Kline & Co., a Metuchen, NJ, market research firm.

The advanced materials industry, which includes advanced composites, polymers, metals, and ceramics, is in the midst of a technological explosion that is creating major economic opportunities for companies willing to commit technical resources.

Eckert singles out 11 companies as active players in advanced materials—Alcoa, Allied-Signal, Dow Chemical, DuPont, General Electric, ICI, Norton, BASF, Hercules, British Petroleum, and Ciba-Geigy. ☐



Advanced composites, with 10% annual growth, are the fastest growing materials market segment. For more materials research information, see the Perspectives section.

Lab robotics settle down

The rapid growth that characterized the laboratory robotics market a few years ago seems to be over, but the worldwide market still is expected to continue to expand more than 7% annually to $45 million in 1993, according to Strategic Directions Intl., a Los Angeles-based marketing research firm.

The leading industrial users of laboratory robotics systems work in pharmaceuticals, chemicals, petroleum, or biotechnology. The majority of applications are in process and product analytical support and applied R&D and quality control in life sciences.

Do you know what your competitors are doing? consultant asks

WITH TODAY'S climate of rapid technological change, where your competitors introduce and improve products daily, the need for competitive intelligence is increasingly important, says Michael Esposito, a vice president of Arthur D. Little Inc., a Cambridge, MA-based management and technology consulting firm.

"Competitive surprises can put a company out of business," says Esposito. A company needs to know early on what technologies the competition is working on so it can respond to changes appropriately.

"Competitive intelligence is not corporate spying," Esposito says. It doesn't involve breaking into offices or buying information from disgruntled ex-employees, he says.

You can get almost everything you need from public information, such as magazine and newspaper articles, annual reports, filings for debt or stock offerings, speeches and articles by scientists, and reports from securities analysts.

Computerized databases also can be used to access thousands of jour-

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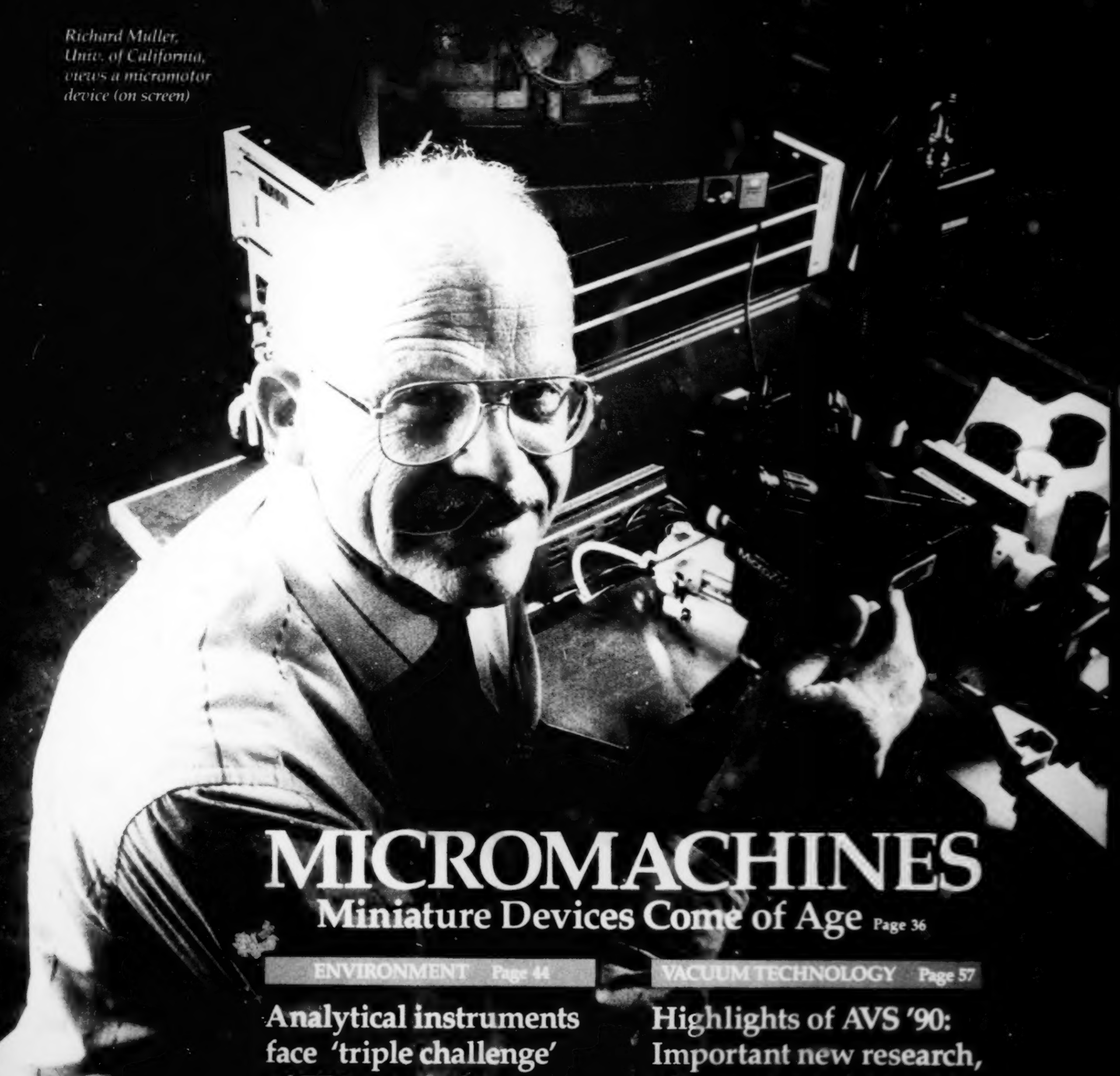

Richard Muller, Univ. of California, views a micromotor device (on screen)

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Miniature Devices Come of Age Page 36

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Analytical instruments face 'triple challenge' of EPA regulations

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Highlights of AVS '90: Important new research, plus some controversy

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Micromechanisms are being used in sensors and actuators today, with research being performed on the microrobots of tomorrow.

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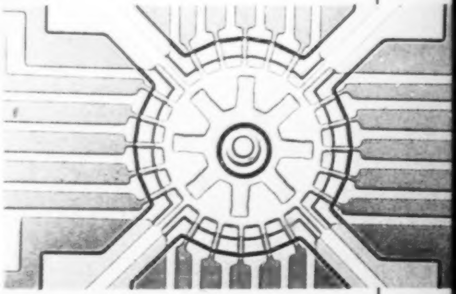
This year's AVS Symposium in Toronto was chock full of new developments and controversy. AVS '91 in Seattle promises more of the same.



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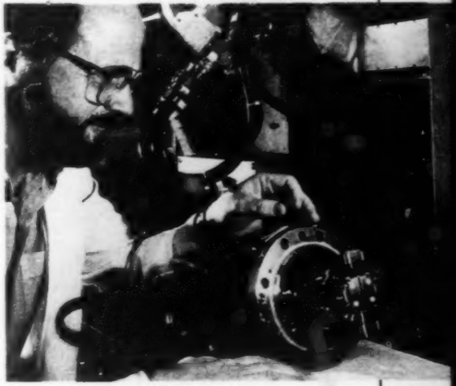

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Cover photo: Tim Davis

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BUSINESS

Japan struggles to build basic research efforts

JAPAN'S BASIC RESEARCH expenditures grew from $8.3 billion in FY87 to $8.6 billion in FY88, a 3.6% increase. In the same period, applied research spending grew 8.3% and developmental research grew 9.9%, according to Japan's latest government survey.

Unfortunately for those Japanese researchers wishing to impress upon the world that they are sincere about becoming a source of basic research knowledge, the portion of Japan's total R&D expenditures devoted to basic research fell from 14% in FY87 to 13.3% in FY88.

Japanese industry's commitment to commercial development continues to dominate the nation's R&D spending, rising from $25.9 billion (60.6%) in 1983 to $40.3 billion (62.4%) in 1988.

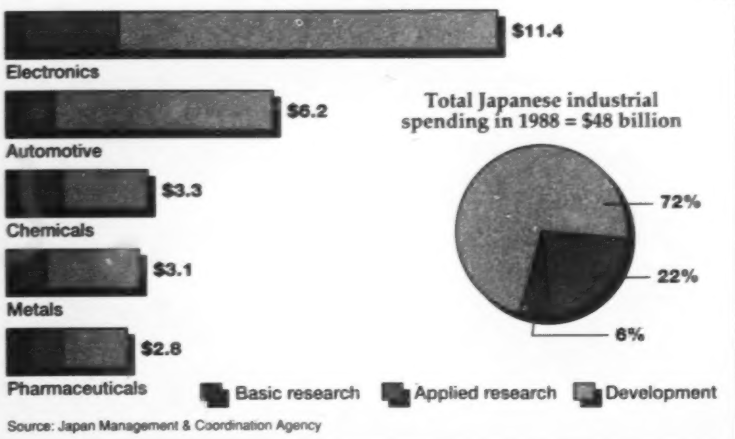
Basic research in Japan is in gradual decline in many areas. Even university- and research institution-funded basic research had smaller shares of the total R&D spending in 1988 than in 1987. Basic research in universities fell from a 54.2% share of their total research in 1987 to a 52.8% share in 1988. In Japanese research institutions, basic research fell from a 15.8% share in 1987 to 14.9% in 1988.

Japan's Human Frontiers Science Program (HFSP) typifies its problems with basic research programs. HFSP, a 20-year international program to explore basic biological functions, was proposed by Japan in 1986. Japan committed to pay up to half the $6.7 billion cost, but funding was delayed by the government until FY89.

Even after Japanese funding was approved, which amounted to 35% of the international commitment, Japanese researchers were awarded only 5% of the basic research work.

—Tim Studt

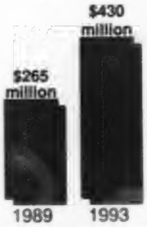
Japanese industries focus on the 'D' in R&D
(in billions)



Source: Japan Management & Coordination Agency

Japanese chemical, metals, and pharmaceutical firms spend 7% to 19% of their R&D budgets on basic research, while automotive and electronics firms spend less than 5%.

Mass spectrometers to grow 13% annually



Worldwide sales of mass spectrometers (not including GC-MS or LC-MS) are forecast to grow nearly 13% annually through 1993 to $430 million, according to Strategic Directions Intl., a Los Angeles-based market research firm.

Currently, U.S. and Canadian sales account for more than 50% of the world market for mass spectrometers. This number will decrease as the European market grows because of increasing environmental concerns.

Report lists more than 250 new applications for laser technology

FROM MEASURING THE concentration of cow methane in a field to sizing and possibly even controlling the formation of tornadoes, many new market opportunities exist for emerging laser systems, according to a report by William Truett, president of Truett Scientific Co., West Brattleboro, VT.

More than 280 current applications and more than 250 new applications in 32 different areas are listed in the study.

In one potential application, the methane concentration in a field filled with cows could be measured precisely with a CO_2 gas laser or lead-acid salt-tuned laser diodes.

LADAR (laser detection and ranging) systems currently are the only operational systems for detecting turbulent air. High-powered airborne CO_2 or Nd:YAG laser systems, however, could control the formation of some turbulent air systems, such as tornadoes, according to Truett.

For a copy of *New & Emerging Laser Applications, A Technical Forecast* ($495) call 802/257-9409. ☐

Researchers get free access to funding sources

RESEARCHERS AND TEACHERS in nonprofit institutions can obtain free access to a database listing public and private funding resources for the purchase of laboratory equipment in a program made available by Spectra-Physics, San Jose, CA.

The database lists the sources, addresses, deadlines, and application procedures for obtaining grants to purchase chromatography and electrophoresis instruments and chromatography data management systems.

continued

Environmental Instruments Meet a Triple Challenge

Researchers are coming up with new analytical instruments that are fast, simple to use, and extremely reliable.

By Tim Studt, Associate Editor, R&D Magazine

R D *Perspectives*

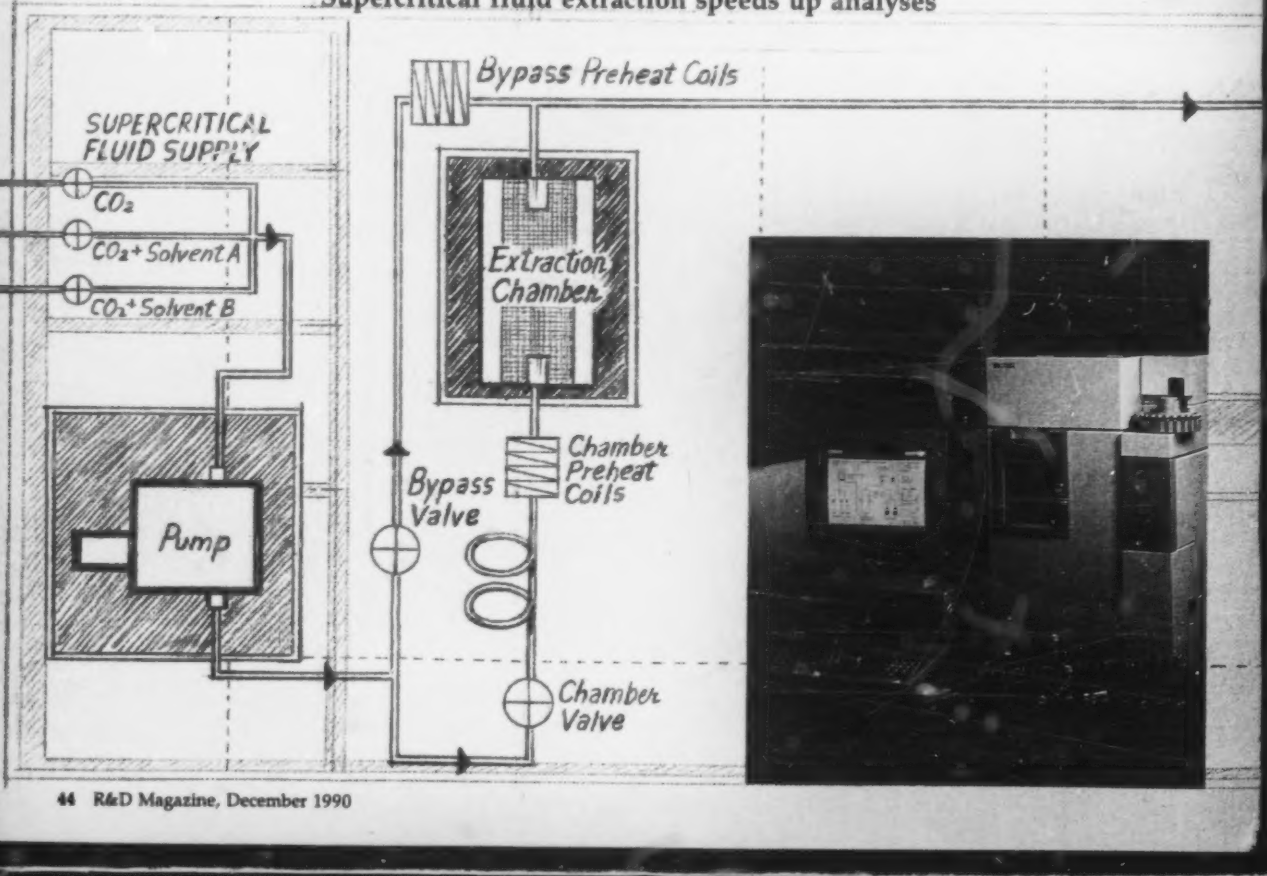
RESEARCHERS CHARGED with producing new instruments to monitor the environment face three obstacles: speed, simplicity, and reliability.

They need to make instruments that shorten the time needed for analysis, make it easy to perform tests in the field, and operate reliably. If the instruments also can measure some previously unknown threat to the ecosystem, that's a bonus.

Instrument makers are meeting the triple challenge of speed, simplicity, and reliability with new devices in four key areas:

- **supercritical fluid extraction,** a faster system for sample preparation
- **environmental immunoassay,** a test procedure for quickly screening samples in the field
- **an improved GC-MS system** that meets U.S. Environmental Protection Agency (EPA) methodology and keeps on running

Supercritical fluid extraction speeds up analyses


SUPERCRITICAL FLUID SUPPLY
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Pump
Bypass Preheat Coils
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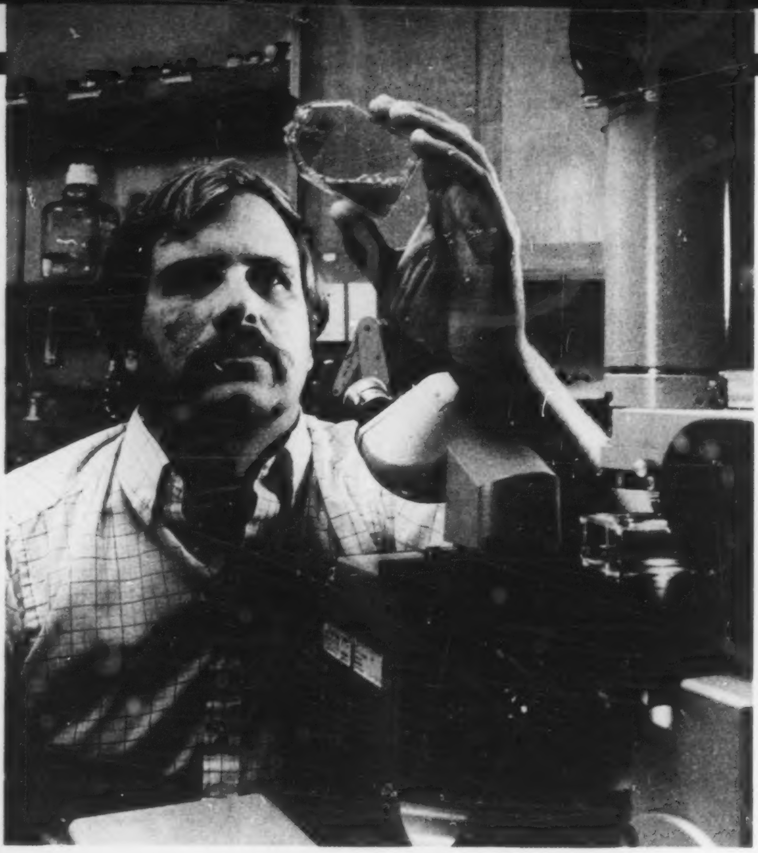


Marty Vanderlaan, *a scientist at Lawrence Livermore (CA) National Laboratory holds a flask of monoclonal antibodies used to screen for dioxins.*

- **an ion-assisted system** that reliably measures short-lived OH radicals.

When characterizing an air, water, or soil sample for environmental purposes, you have to extract specific compounds from the sample before it can be injected into an analysis system, such as a gas chromatograph, liquid chromatograph, or nuclear magnetic resonance instrument.

You could use conventional extraction techniques, such as soxhlet extraction or liquid-liquid extraction, but they require a lot of time and labor.

Taking faster samples

Supercritical fluid extraction (SFE) offers substantial time and labor savings over these techniques.

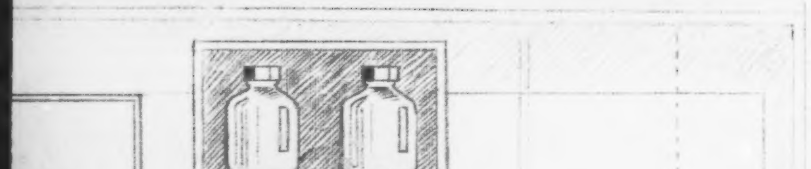
"An EPA soxhlet procedure that requires 18 hours to complete can be done in about 15 minutes with SFE," says Stuart Cram, a federal programs manager at Hewlett-Packard, Palo Alto, CA. "Liquid-liquid extraction techniques requiring 36 hours can be done in 20 minutes with SFE."

SFE can be used for extraction of analytes, such as PCBs, pesticides, and herbicides from soil, sludge, and animal and vegetable tissue. Besides saving time, SFE eliminates the need for the hazardous chlorinated solvents used in other extraction methods.

SFE instruments use CO_2 to perform the extraction. This allows you to extract nonpolar compounds, but makes it impossible to measure polar and/or ionic compounds.

Researchers have found that adding 1% to 3% methanol to the CO_2 allows you to extract more compounds. They still need to develop the methods for quantitatively controlling the doping of methanol, a liquid, to CO_2, a gas.

Researchers at Lawrence Livermore (CA) National Laboratory (LLNL) have developed a series of monoclo-



Carbon dioxide *is used as the solvent in this supercritical fluid extractor (inset and schematic) because of its ease in creating a supercritical* CO_2 *state, low boiling point, and nontoxicity. The large extraction samples in the autosampler vials can be transferred and injected into gas, liquid, or supercritical fluid chromatographs for analysis.*

Environmental immunoassays can be used to screen samples for dioxins and insecticides in the field.

nal antibody test procedures, or immunoassays, that can be used to detect the presence of pesticide residues, mycotoxins, and industrial chemicals.

Just as blood samples can be tested for the HIV factor or drugs, environmental immunoassays can be used to screen samples for trace residues in the field. If samples test positive, they then can be sent for full laboratory analysis.

Immunoassays also can measure compounds that are not measurable by other means, such as pyrethroids—a class of insecticides not monitored because they are not measurable by conventional means.

LLNL researchers have developed monoclonal anitbodies for dioxin, cyclodiene insecticides, pyrethroid insecticides, and dimetridazole, a veterinary drug.

Immunoassay systems also can be used quantitatively. "When combined with HPLC (high-performance liquid chromatography), our immunoassays can offer a 1,000-fold increase in sensitivity over HPLC-UV systems," says Martin Vanderlaan, a chemist at LLNL.

Improving reliability

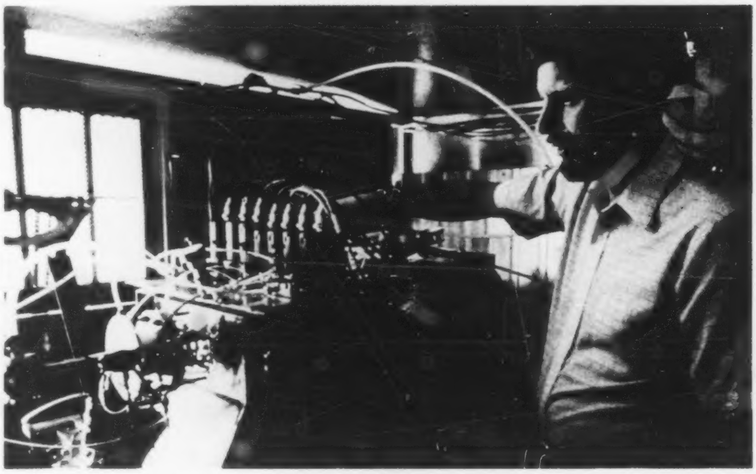
EPA's test method 625 requires measurement down to the parts-per-billion range in chemical sampling. Most GC-MS systems can measure to these levels, but you have to shut them down after five to 10 days for maintenance, which itself takes a day or two.

Then there is EPA method 525, which has a limit of 400 parts per trillion (ppt). A few instruments can measure to this level, but you have to shut them down for maintenance after only 12 hours of use.

Researchers at Oak Ridge (TN) National Laboratory (ORNL) have developed a GC-MS system with 100-ppt accuracy that they have run continuously for more than six months.

"We've corrected the front end so what you put in at the GC is now delivered to the mass spectrometer," says ORNL chemist Quirinus Grindstaff.

Researchers at Georgia



Fred Eisele, a scientist at Georgia Tech, Atlanta, uses this mobile ionization instrument to measure the amount of short-lived OH radicals in the atmosphere.

The environmental market: diversity and growth

THE MARKET FOR analytical instruments used to assess environmental conditions should grow more than 14% annually, to $2.25 billion in 1994, according to Strategic Directions Intl., a Los Angeles-based market research firm.

When taking inflation into account, this growth is nearly double that forecast by the U.S. Dept. of Commerce for analytical instruments in general.

Environmental instruments can be grouped into those used in laboratories, such as chromatographs, mass spectrometers, and atomic spectroscopy products, and those used in the field, such as source analyzers and radiation detectors.

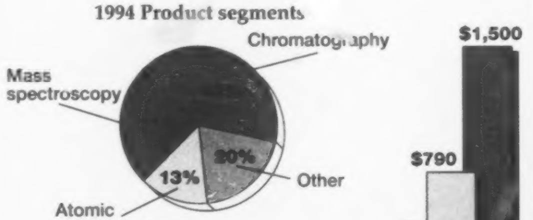
"Non-laboratory instruments used for air analysis have the largest growth forecast (+21%) because much of the emphasis on environmental regulations worldwide is toward air quality, and these instruments are growing from a relatively small base," says SDI president Lawrence Schmid.

The best-selling categories of the combined environmental instruments market are those used for water analysis (58% of the total in 1989) and air analysis (12%). By 1994, water analysis instruments will have 60% of the total, air analysis instruments 12%, says Schmid.

The biggest customers for environmental instruments are government agencies, independent test labs, and energy and water utilities, consuming 58% of all such sales in 1989.

Double-digit growth in environmental instruments

(World market in millions of U.S. dollars)



Source: Strategic Directions Intl.

After running for more than six months, a new GC-MS still measures down to 100 parts per trillion.

Tech Research Institute, Atlanta, have developed a technique that measures the amount of OH radicals in the air.

OH radicals remove pollutants in the atmosphere, such as methane, carbon monoxide, and certain halocarbons. If OH levels are changing, the CFC replacement halocarbons could be worse for the atmosphere than the CFCs are for the ozone layer.

New OH radicals are generated every day by sunlight reacting with ozone in the air. They survive for about one second before reacting with other compounds.

Given OH's short life, scientists find it difficult to determine if OH radicals are decreasing or increasing. Conventional techniques for measuring OH, such as optical long-path absorption, are cumbersome and unreliable.

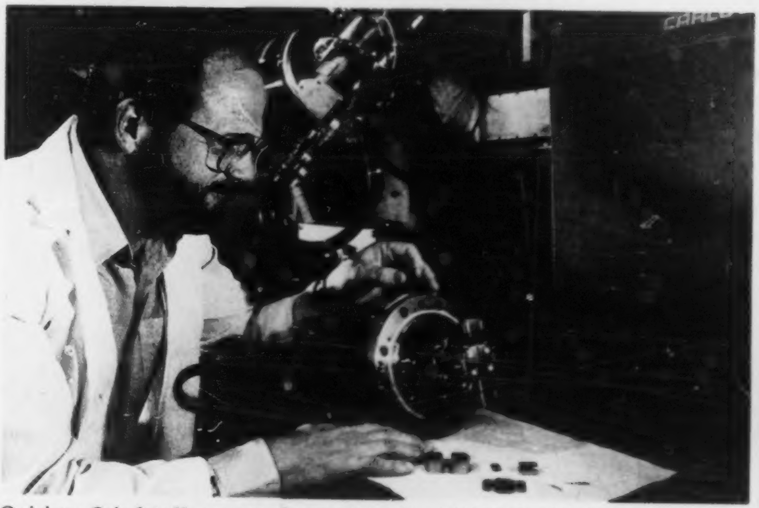
Fred Eisele, a principal research scientist at the Georgia Tech lab, accidentally discovered a way to determine OH levels as he was measuring ions being formed under high-voltage power lines.

He noticed that the rise and fall of mass spectrometer signals for sulfuric acid ions corresponded to changes in incident sunlight. Eisele realized that sulfuric acid was being produced in correlation to the production of OH.

He developed a system that injects nitrogen and sulfur dioxide into ambient air samples. These gases then ionize to create sulfuric and nitric acids. "Using the reaction rates and times involved, we can measure the amount of OH radicals in the initial sample," says Eisele.

This ion-assisted system can measure OH at 1×10^5 molecules/cm^3, several decades lower than other systems. Additionally, by having a different methodology, it can be used to compare results with other systems.

Stuart Cram describes SFE as a system with "high demand, high anticipation, and a very high need." With ever increasing environmental problems, you can say the same of GC-MS, environmental immunoassay, and OH instruments. **R&D**



Quirinus Grindstaff, a researcher at Oak Ridge (TN) National Laboratory, examines a GC-MS system that samples down to 100 parts per trillion with little maintenance.

Common techniques for measuring the environment

Matrix	Analyte	Instrument technique
Drinking water and wastewater	Organic compounds	Gas chromatography
		Gas chromatography-mass spectrometry
		Liquid chromatography
		Fluorescence
	Metals	Atomic absorption
		Graphite furnace atomic absorption
		Inductively coupled plasma emission
		Inductively coupled plasma-mass spectrometry
		Ultraviolet/visible spectroscopy
	As, Se, Hg, N, P, cyanide, fluoride, sulfate, phenolics, chloride	Mercury/hydride atomic absorption
		Ultraviolet/visible spectroscopy
	TOC	Organic elemental analysis systems
Solid waste	Organic compounds	Gas chromatography
		Gas chromatography-mass spectrometry
		Liquid chromatography
	Metals	Atomic absorption
		Graphite furnace atomic absorption
		Inductively coupled plasma emission
		Inductively coupled plasma-mass spectrometry
Air	Organic compounds	Gas chromatography/thermal desorption
		Gas chromatography-mass spectrometry
		Organic elemental analysis systems
	Metals	Atomic absorption
		Graphite furnace atomic absorption
		Inductively coupled plasma emission
		Inductively coupled plasma-mass spectrometry

Source: Perkin-Elmer

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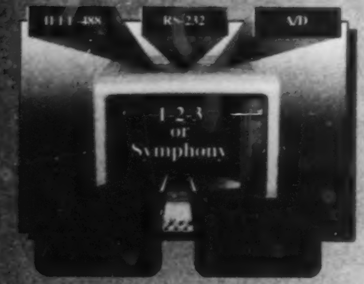

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ABOUT THE COVER Alan Huang demonstrates AT&T Bell Lab's prototype digital optical computer, which operates with light instead of electricity. *Photo courtesy AT&T Bell Laboratories.*

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R&D BUSINESS

More Restructuring Needed to Offset High Pharmaceutical R&D Costs

"Rising R&D costs and generic substitution of prescription drugs will force more pharmaceutical companies to merge in the 1990s," says Mason ("Skip") Irving, manager of Arthur D. Little's Health Care practice.

"The pharmaceutical industry is quite fragmented," says Irving. The 10 largest companies in the world only have 20% of the market, a ratio that is well below that of other industries.

The main problem is rising R&D costs and their effect on profitability. A pharmaceutical firm can take eight to 12 years to develop one new drug, while incurring development costs of up to $200 million. Over the past 10 years, pharmaceutical firms have had to increase their R&D spending from 11% of sales to more than 16% of sales to offset these cost increases.

A company might not have very long to make up those costs. Since most drug patents are filed five to six years into development, a marketed drug has only five to eight years of patent exclusivity before generic substitutes can be introduced.

In most cases, the generic substitute will take away more than half of a drug's market within three years of the generic's introduction.

Given these economic realities, fewer drugs will be profitable than have been in the past, says Irving.

"Pharmaceutical firms are changing the way they do their R&D," he says. "They're planning product development in a much more structured manner than before."

Product managers now not only have to decide which drugs should be developed, but also how they are going to be positioned and how much patent life they will have.

But just changing the way R&D is performed won't be enough to change the overall economics. More restructurings are essential to fund the level of R&D that is necessary.

Only a few pharmaceutical firms have merged so far, including SmithKline Beecham, Bristol-Myers Squibb, and Marion Merrell Dow. As a result of future mergers, Irving predicts that the 10 largest pharmaceutical firms in the year 2010 will have nearly 40% of the market, a number that should justify the large development costs of new drugs. *—Tim Studt*

Top 10 Drug Companies

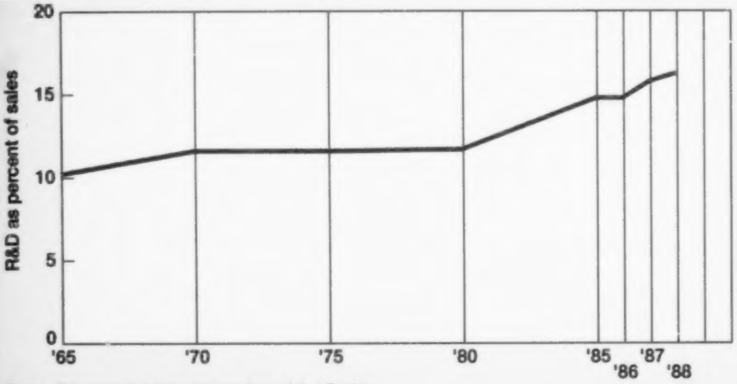
1989 sales*

1	Merck	5.4
2	Bristol-Myers Squibb**	5.2
3	Glaxo	5.0
4	SmithKline Beecham**	4.4
5	Hoechst	4.4
6	Bayer	4.0
7	American Home Products	4.0
8	Ciba Geigy	3.9
9	Takeda	3.9
10	Sandoz	3.5

*Billions of U.S. dollars **Recent restructuring

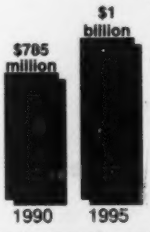
***Increasing development** costs for new ethical drugs, which can exceed $200 million per drug, will force a shakeout of marginally profitable pharmaceutical firms.*

Skyrocketing drug R&D costs will force more restructuring



Source: Pharmaceutical Manufacturers Assn.; Arthur D. Little

Slow Growth for GC Systems



The market for gas chromatography systems is maturing with 6% growth forecast for the next five years, according to Strategic Directions Intl., a Los Angeles-based management consulting firm.

Over the next several years, the U.S. Environmental Protection Agency is expected to approve HPLC for several environmental test methods, which will replace many existing GC methods and cut into the GC instrument growth.

Commerce Dept. Opens Clearinghouse for Technology Ideas

Information from more than 700 local, state, and federal technology programs and from more than 400 individuals working on technology programs is available in a database from the U.S. Dept. of Commerce.

The DOC's recently announced Clearinghouse for State and Local Initiatives on Productivity, Technology, and Innovation classifies programs in 12 categories, including financial and technical assistance. For more information, call 202/377-8100. **R&D**

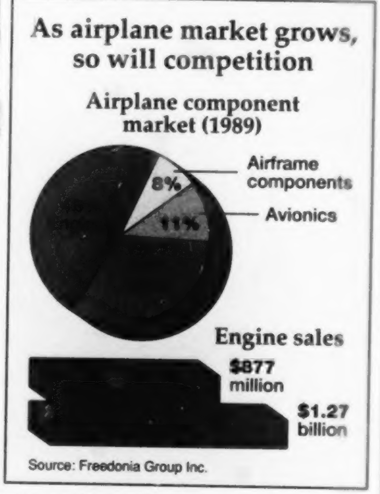
Japan Eyes U.S. Civilian Aviation Lead

An offer to the world's most advanced airplane engine manufacturers to join a Japanese-led supersonic propulsion development program has Western aviation companies sitting on edge.

At stake is a possible piece of the pie for next-generation supersonic transport aircraft, funding commitments for advanced programs, and lucrative footholds into Pacific Rim markets. But these plums will not come without a cost, which could include transfer of technology that the West (particularly the U.S.) has built up in civil aviation since World War II.

"We are not convinced that working with the Japanese is a bad thing," says Bill Robeson of the Aerospace Industries Assn., a Washington, DC, trade group. "But, the Japanese are very competent at making use of the technology that they acquire."

The invitation to participate, the first ever made by Japan's Ministry of International Trade & Industry (MITI) to foreign companies, is designed to give Japan a head start on technology for supersonic/hypersonic propulsion.



Source: Freedonia Group Inc.

***The civilian** airplane market will grow to more than $27 billion by 1994, according to the Freedonia Group, Cleveland. U.S. sales and exports of engines and parts will rise to almost $1.3 billion by 1994, averaging about 8% growth per year.*

Technicians at NASA's Lewis Research Center, Cleveland, install instrumentation on a Mach 5 engine inlet model prior to wind tunnel testing. Japan has invited two leading U.S. engine manufacturers to help them develop advanced propulsion systems and get their fledgling SST project off the ground.

The invitation was made to General Electric's Airplane Engine Div., Evandale, OH; Pratt & Whitney, East Hartford, CT; Rolls Royce Industries, Ltd., Derby, England; and Snecma, Paris. They would work with Ishikawajima Harima Heavy Industries Co., Mitsubishi Heavy Industries Ltd., and Kawasaki Heavy Industries Ltd. to research, build, and test ramjet and turbojet engines for a Mach 5 transport.

Officials at Rolls Royce say they are close to agreement on their part of the $220 million 8-year program.

"We know there will be some tech transfer, but for the area we will be working on (emission systems) it will be beneficial for us," says Brian Lowrie, chief engineer of high-speed propulsion at Rolls Royce.

NASA recently began a high-speed civil transport program, which is aimed at developing technology for a Mach 2.5 to 3 transport. GE and Pratt, traditionally fierce competitors, have teamed up to work in that program.

Some market forecasts project a need for a next-generation supersonic airplane that could cut the travel time from Los Angeles to Tokyo from 10 hours to four.

"In aeronautics, it's economic suicide not to pursue an [SST] project," says Norris Krone, executive director of the Maryland Advanced Development Lab, Greenbelt, MD. "If our engine makers do not get involved in this project, and the NASA project does not take off, then we are really out."

So far, GE and Pratt have kept quiet about the MITI proposal, only saying that they are negotiating terms of participation. Industry experts agree that attention to detail will be the key to any agreement with MITI.

"I don't think there is an inate discomfort in dealing with the Japanese or the Europeans in principle," AIA's Robeson says. "But the devil is in the details."

"It's a big world out there," adds Krone, who has testified to Congress concerning the FSX fighter controversy. "If we don't take part [in the MITI project] other people will."

—Skip Derra

$158 Billion and Holding For U.S. R&D in 1991

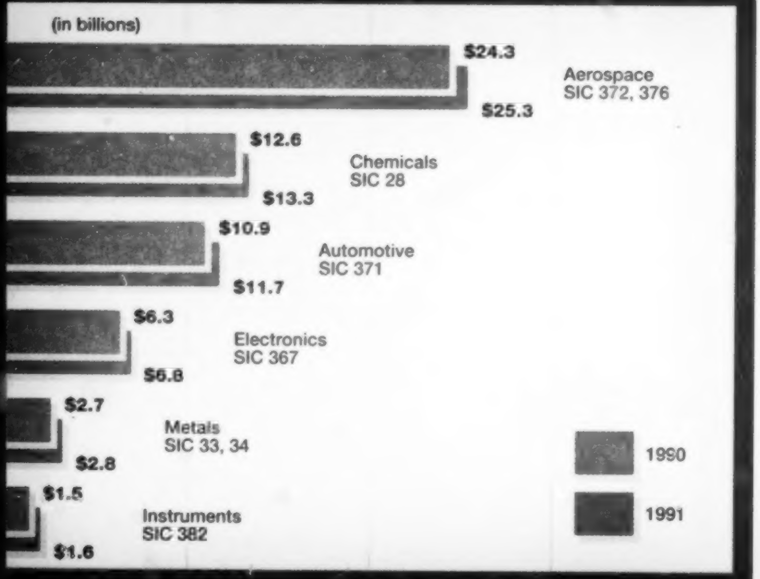
Fears of recession, the budget deficit, and Saddam Hussein make real growth in R&D spending unlikely this year.

*By **Tim Studt**, Associate Editor,* R&D Magazine

Caution is a word that most R&D budget managers are using this year when they describe their 1991 R&D budgets. Fears of a large recession, tight money policies, escalating government deficits, and increasing costs resulting from the Mideast crisis have R&D managers wondering if their R&D funding sources will hold up throughout 1991.

If a recession hits too deeply, industrial research managers might have to balance corporate profitability against their R&D budgets—and that means less money for R&D. Government research managers also wonder if the U.S. Department of Defense (DOD), the largest single research funding source, will cut back on R&D contracts to pay for the Desert Shield buildup. This leaves university R&D managers caught in the middle, wondering if their industrial and government funding sources similarly might soften.

Slow growth of R&D in key industries



Industrial research in 1991 *will have smaller increases than in 1990, often several percentage points lower and sometimes not matching inflation increases, such as those in aerospace (4[illegible] increase) and metals industries (3.7% increase).*

It is in this context that *R&D Magazine* forecasts that Federal, industry, and university and nonprofit research funding sources will spend $158 billion in 1991. This is a 5.3% increase over the $150 billion in research expenditures that the U.S. National Science Foundation indicated would be spent in 1990.

But, after you factor in the current inflation rate, this indicates that research spending will continue in 1991 at the same or even a slightly lower rate than that of 1990.

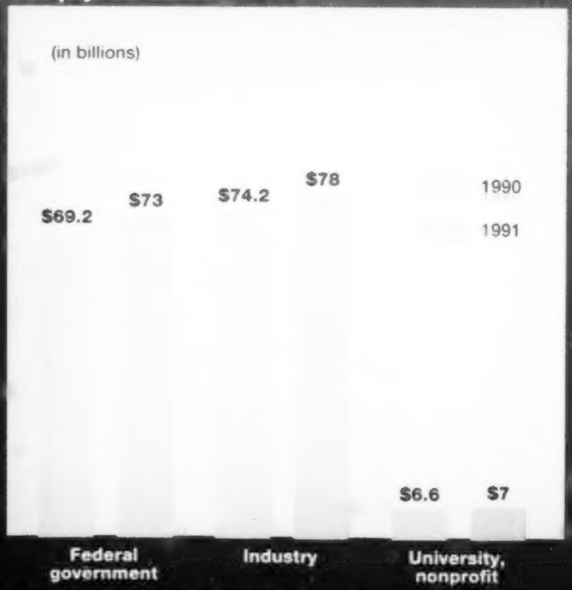
Cahners Economics, Newton, MA, forecasts a 5.0% increase in the 1991 consumer price index. However, for the past 12 months the CPI has been running at 5.5%, up from 4.4% for the previous 12 months, and energy costs could increase these rates even further if the Mideast crisis escalates. Economic analysts are modifying their forecasts almost daily in an effort to keep up with changing economic and political conditions.

An additional economic factor is that research costs normally escalate at a rate that is about one percentage point higher than the CPI.

"The higher education price index, an index that tries to estimate the cost of institutional purchases, has always run about 1% higher than the CPI," says Roland Schmitt, president of Rensselaer Polytechnic Institute, Troy, NY. "If you ask industries about their research costs, they would probably

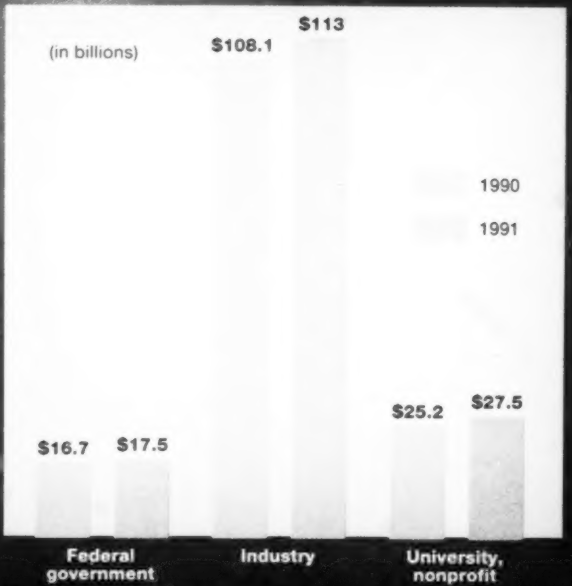
U.S. R&D to reach $158 million in 1991

Who pays for U.S. R&D



Research funding sources *will increase their monies in 1991, but will monitor the economy throughout the year and make adjustments down each month or quarter if necessary.*

Who does the work



University research centers *will increase their share of the total research workload, but they will see smaller growth (9.1%) than in the past two years (10.4% average growth).*

'We try to keep a steady investment in research, rather than jerk it up or down,' says IBM's Marc Brodsky.

be 1% above the CPI also."

There is the possibility that university research costs might even increase beyond this level (see box).

Research funding and spending in 1991 will follow similar patterns to those in previous years. The Federal government and industry will provide more than 95% of the funds, but Federal labs will perform only 11% of the work, while industry will perform 71.5%. Both these performance shares are down slightly from 1990 shares, as university and nonprofit research pick up more work for a 17.4% share, up more than a half percentage point from 1990.

Industrial uncertainties

Most companies are holding their 1991 R&D expenditures to 1990 levels or adding only slight increases, after adjusting for inflation. "When the Washington, DC-based Industrial Research Institute surveyed its members recently, "an overwhelming number of respondents indicated they expect to maintain or slightly increase their R&D budgets in 1991," says Philip Brodsky of Monsanto, chairman of the IRI's research committee.

Companies that grew during the fierce competitive and takeover pressures of the 1980s feel they are in a fairly strong position today with confidence in the competitive technology of their products.

Research managers realize that foreign competitors in Japan and Europe are continuing their R&D spending, so they don't want to jeopardize their own competitiveness by cutting back too much on R&D.

Thomas Brick, president of Keithley Instruments, Cleveland, speaks for many industrial research administrators: "The very last thing I would do is cut back on my new product development, where I felt it would put me at a competitive disadvantage."

Moreover, most industrial companies have not seen any economic changes yet that would have an effect on their immediate research funding capabilities. Many companies have an increasingly strong export trade.

"However bad the overall economic news gets [about a recession], it will not be as bad for industrial companies as it is for consumer companies," says Kermit Baker of Cahners Economics.

Big industrial R&D spenders, such as IBM, 3M, and Boeing, have the resources to ride out the first year of an economic slowdown. They continue to spend on R&D at the same rate as they have for the past few years.

"We try to keep a steady investment in research over the years rather than jerk it up or down," says Marc Brodsky, director of the technical staff at IBM Research, Yorktown Heights, NY.

Ronald Mitsch, senior vice president of R&D at 3M, St. Paul, MN, doesn't see any big changes either. "We've been spending about 6.5% of sales on R&D and we'll be continuing in that range [for 1991]," he says.

Despite severe cutbacks in major military programs, the aerospace division of Seattle-based Boeing will continue with its level of R&D spending in 1991, according to a Boeing spokesman. The commercial airplane division of Boeing has backlogs of airframe orders through the year 2000, which will support its R&D programs at their present rate.

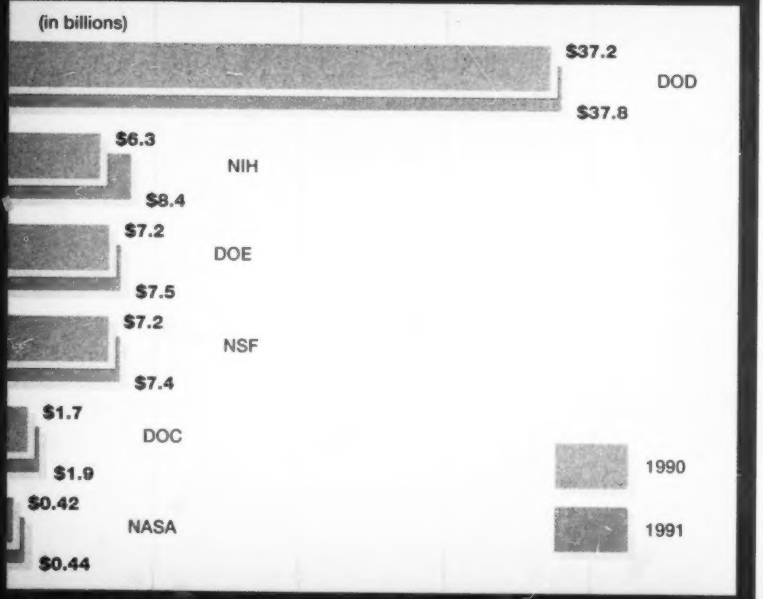
Midsize companies don't have the same capability to ride out economic cycles as do large companies. But most of these companies also are not drastically altering their R&D budgets in 1991.

"So far our business is relatively good," says Alan Bennett, vice president of R&D at Varian Associates, Palo Alto, CA. "On the other hand, there are all these clouds on the horizon, and I'm sure that if things start to look bad, we'll batten down the hatches in R&D and in many other areas as well."

Some small companies often are unaffected by changes in the larger economy. "Our business has been anticorrelated with the macroeconomy," says Richard Blattner, vice president for Charles Evans Associates, Redwood City, CA. "Our research business through the Small Business Innovative Research (SBIR) program is expected to double next year.

"There appears to be a larger number of contracts being let at lower dollar amounts," he says. "Several government agencies have lowered the ceilings on these contracts to accommodate smaller budgets or to get more companies involved."

continued



Defense still dominates Federal R&D

Defense research continues *to have the largest share of the federal budget, but its share will drop two-percentage points in 1991, to 51.8%. Additional defense share decreases are forecast for the future as overall defense spending decreases and the research balance shifts to a more commercial-based emphasis.*

'We're putting increased emphasis on shorter term research instead of blue sky efforts,' says Varian's Bennett.

Will the 1990s take the bloom off university research?

"I'm budgeting for much lower research growth in 1991—only 5%, compared to 15% growth in 1990," says Roland Schmitt, president of Rensselaer Polytechnic Institute, Troy, NY. "But, frankly I don't know how much credence to put into that."

This uncertainty for future funding sources faces many university research administrators. With smaller government and industry research increases and a recession almost assured, the double-digit growth that many university research administrators have enjoyed for the past few years seems to be a thing of the past.

In the past five years, while research at government and industry facilities grew by 8% in real dollars, research at universities grew by 28%, according to the National Science Foundation.

However, the very items that make university research attractive, that of lower costs and high-quality research, are being hurt by demographics and the technology itself.

"We see an extraordinary and unexpected increase in the costs we expend to indirectly support research," says Judith Liebman, vice chancellor of research at Univ. of Illinois, Champaign. "The utility, health, and environmental safety costs of our research labs have increased far faster than the normal inflationary increases."

"Even library costs have gone through the roof," says Liebman. "Foreign technical journals have increased 30% in price."

Top 10 Schools For R&D Spending

	(in millions)
Johns Hopkins Univ.	$648
Massachusetts Institute of Technology	$287
Cornell Univ.	$287
Stanford Univ.	$286
Univ. of Wisconsin, Madison	$286
Univ. of Michigan	$281
Univ. of Minnesota	$259
Texas A&M Univ.	$251
Univ. of California, Los Angeles	$228
Univ. of Washington	$222

These costs are carried over to the research funding agency in the form of overhead. Univ. of California, Berkeley, actually had to forgo normal university overhead for its Sensor and Actuator Center so that it could receive NSF funding.

Possible shortages of researchers are another problem facing university administrators in the next decade.

In the 1980s, foreign PhD recipients who decided to stay in the U.S. after graduation made up much of the domestic shortfall in doctoral-level researchers.

"In some instances, these people are now going back home as their home country economies grow and improve," says Rensselaer's Schmitt. "Add to this the fact that there will be a large increase in the number of people retiring from science and engineering university faculties at the end of the decade, and I get a little apprehensive [about university research]."

However, the competition for these contracts has nearly doubled over the past five years as more people find out about them, according to Blattner.

Unusual government business

A strange thing happened at Georgia Tech, Atlanta, this past October. After having 10% to 15% growth in its research for the past 10 years, the income for new awards was down significantly from October 1989 levels.

"I called up several other universities to see if we had a particular problem," says Demetrius Paris, vice president for research and graduate programs at Georgia Tech. "What I found out was that a lot of Federal research funding agencies, not knowing how much money they had in the Congressional battle over funding the Federal deficit, did not make any awards during October 1990."

In the confusion, contracts were delayed, lost, or overlooked. Four million dollars promised to support a high-energy physics program at Fermi National Accelerator Laboratory, Batavia, IL, had to be hunted down at the last minute by U.S. Rep. Dennis Hastert, the district's congressman, to avoid being lost.

"What we're seeing is an uncertainty and how long that is going to last is anyone's guess," says Georgia Tech's Paris.

The slowing economy, the savings and loan bailout, and Operation Desert Shield all will continue to add to the Federal budget deficit, which will bring about more such situations in the future.

For the time being though, government agencies are again funded and reissuing research contracts at a level that is as good as or better than that in 1990, except of course for defense research.

Smaller defense and defense research budgets, while still large, will result in at least a few corporate restructurings as defense contractors slash spending to survive lean times.

Changes in direction

Basic research makes up about 14% of the total amount of the U.S. R&D budget, of which 70% is performed in university and nonprofit centers, according to the NSF. Economic and competitive pressures appear to be reducing this section in favor of more applied and development research.

"We're putting increased emphasis on shorter term research instead of blue sky efforts," says Varian's Bennett. "We made a decision to focus as much of our resources as possible to make Varian as profitable as we can, which we hope will create more money for R&D on a longer term."

Asked what specific challenges they have for the next 12 months, R&D managers overwhelmingly stated that managing the mix of projects that technology has made available is their biggest challenge. "You always have to advance specific technologies along a trend line," says IBM's Brodsky. "But you also have choose the right product from the technical opportunities that are out there." **R&D**

READER RESPONSE PANEL

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Because semiconductors are at the low end of their cycle, the vacuum industry will be down 10% to 20%.

The semiconductor industry has driven vacuum manufacturers to achieve higher and higher levels of purity with its systems. This is part of one vacuum equipment trend that Hablanian sees taking hold in the industry over the next five years.

The emphasis on particle-free environments is forcing systems designers to be more careful about the components they choose.

"Particles form by processes themselves, but they also form by pumps and valves and other components," he says. "All of the lines, all of the little fittings that are used in bringing a gas into the chamber, have to be relatively particle free.

"This is fairly serious in some cases and some vendors are seriously evaluating components before they choose them," Hablanian says.

Another trend is toward ultrahigh vacuum. Hablanian says the requirements for initial and process purity are driving companies in some cases to UHV systems.

"In other words, you have to get down to 10^{-9} torr before you can get into your process," Hablanian says. "It puts a considerable amount of stress on the system and pump design."

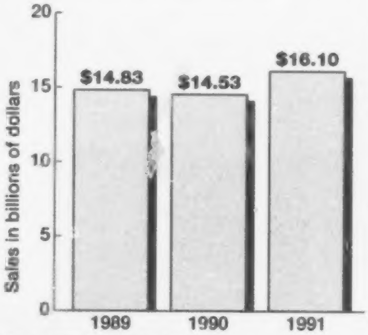
A third trend is in the use of oil-free pumps. Hablanian says this trend goes in two directions.

"One is toward multistage root-blower type or similar systems, which essentially have no liquid oil in the

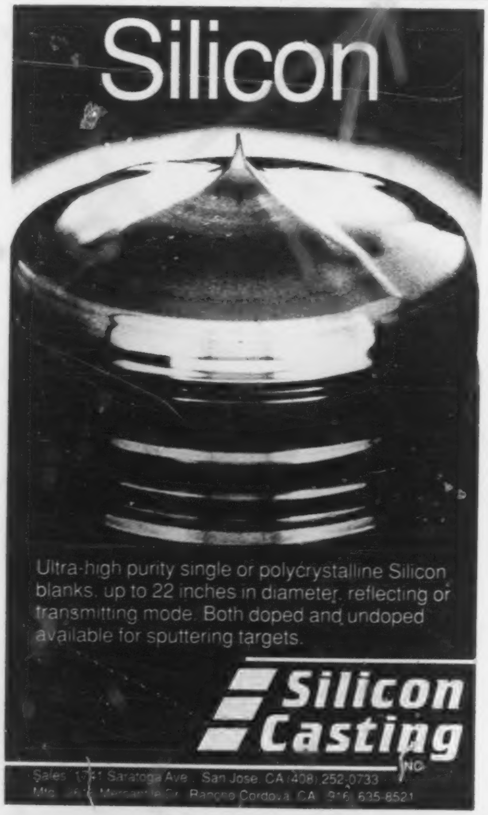
Slow growth predicted for semiconductor market

Semiconductor sales in the U.S. and Canada will rebound this year (+10.8%) after experiencing a slight downturn (−2.1%) in 1990, according to analysts at Cahners Economics, Newton, MA. While double-digit growth for the semiconductor industry is good, don't plan on seeing huge increases in the future.

"Business cycles for semiconductor sales will be muted in coming years," says Julie Handelman of Cahners Economics. Growth is expected, but you will not see a 30% gain in sales like what happened in 1988, she adds.



Forecasts: Cahners Economics
Source: Semiconductor Industry Assn.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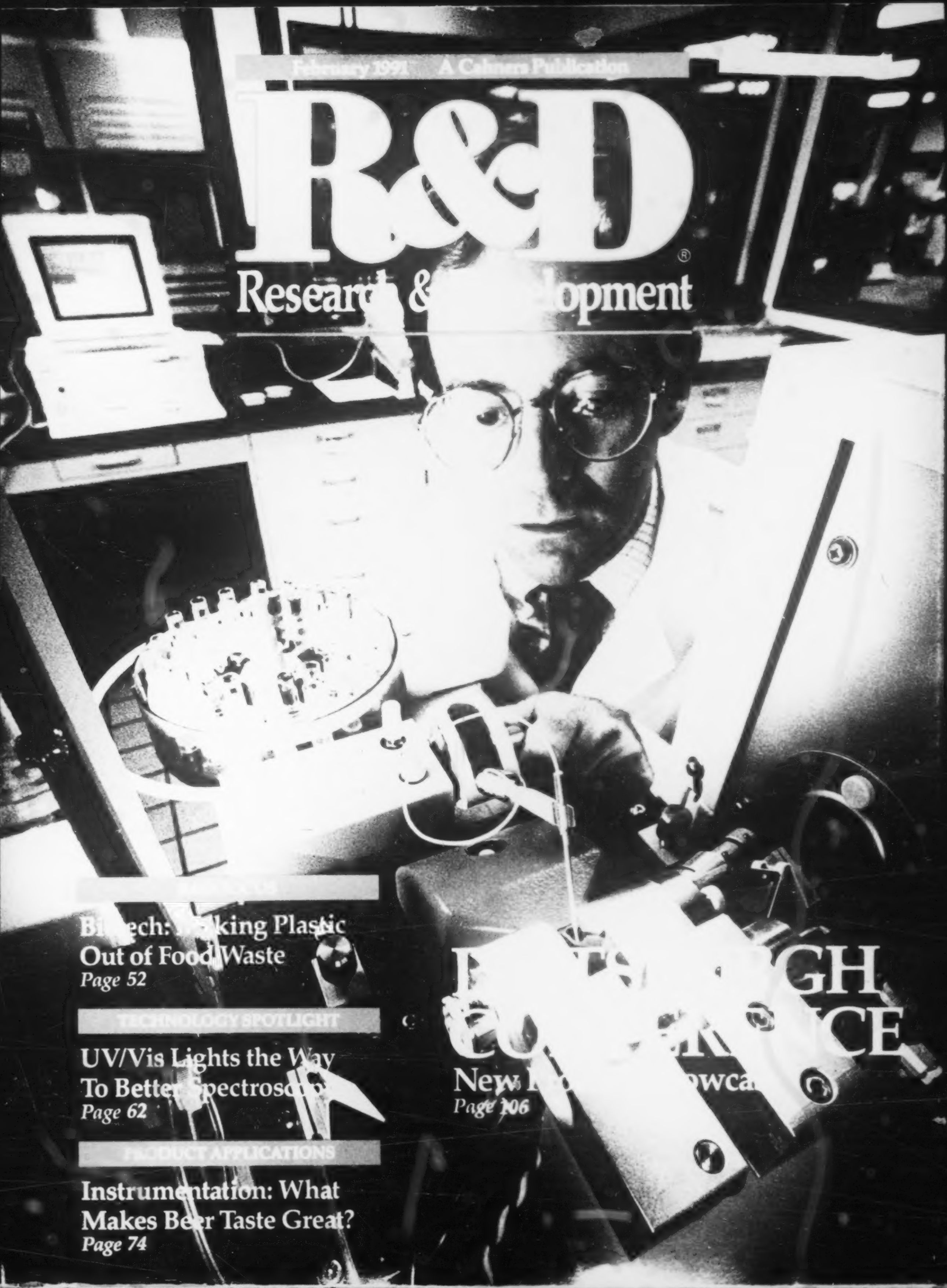

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ABOUT THE COVER Chemist George Greene uses an atomic absorption spectrophotometer, typical of the instruments being shown at the Pittsburgh Conference. For more about new products at Pittcon, please turn to page 106. *Photo by Dana L. Duke, courtesy Perkin-Elmer Corp.*

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Regional Distribution of Spending for University Research Is Changing

Researchers in universities along the Atlantic coast from Maryland to Florida received 12% more in real dollar funding in 1989 over what they received in 1988, according to a recent U.S. National Science Foundation study. This growth is nearly five percentage points higher than that of the next closest region and more than three times the spending increase of Pacific Coast universities.

In fact, 1989 was the sixth consecutive year that this area experienced double-digit growth in university R&D funding. No other region came close to this type of growth.

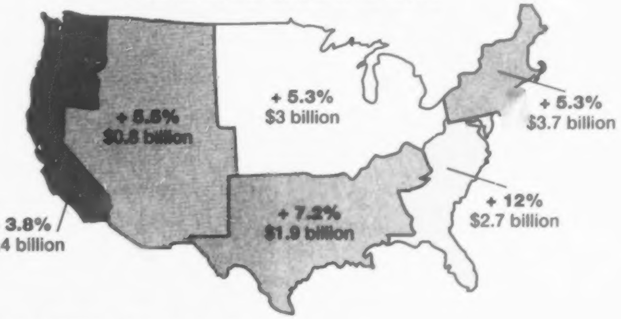
Nearly a quarter of the $2.7 billion spent on research in South Atlantic Coast states was performed at one place—Johns Hopkins Univ., Baltimore. The Applied Physics Laboratory at Johns Hopkins alone received $431 million in R&D funding, of which $422 was federally financed. But even excluding Johns Hopkins, the average increase from 1988 to 1989 is still 12%.

Part of the reason for this dramatic growth is historical. Outside of Maryland institutions, most South Atlantic universities have relatively new research programs. With the recent emphasis on attracting high-tech businesses with strong local university research programs, many states have made dramatic increases in their university research departments.

"We've only been in the research business for the past 20 years," says Demetrius Paris, vice president for research at Georgia Institute of Technology, Atlanta. "We've experienced tremendous growth since then and we're still growing."

Florida, one of the fastest growing states in the U.S., has significantly upgraded its research capabilities. Four Florida universities are listed in the NSF's top 100 institutions for receiving research funds. Univ. of South Florida, Tampa, for example, currently listed 80 on this list, increased its funding 51% from 1988 to 1989 and by more than 400% in the past three years. ☐

More University Research Dollars Headed Southeast in 1989

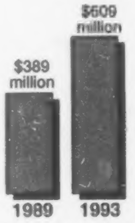


* Percentage increases adjusted for inflation

Source: U.S. National Science Foundation

***R&D spending at universities** that grant a graduate science or engineering degree has increased at a higher level in Southeastern states than elsewhere in the U.S.*

Steady Electrochemistry Instrument Growth



The market for instruments that measure the electrical characteristics of chemicals is forecast to grow nearly 12% annually to $609 million in 1993, according to Strategic Directions International, a Los Angeles-based management consulting firm.

This market includes pH and ion selective electrodes and meters, polarography/voltammetry instruments, and automatic titrators. The pH measurement systems make up more than 50% of the market.

NIST Offers Foreign Standards Hotlines

Two telephone hotlines that provide the latest information on foreign technical standards, certification rules, and regulations are available for U.S. manufacturers and exporters from the U.S. Dept. of Commerce's National Institute of Standards and Technology, Gaithersburg, MD.

One hotline (301/921-4164) contains weekly updated information on draft European Community (EC) laws and standards that might create technical trade barriers for U.S. companies. The recording lists specific subject areas, products, deadlines, and sources for obtaining review copies of the standards and regulations.

Call 301/975-4041 for a weekly updated recording on proposed foreign regulations from the 83 member countries of the General Agreement on Tariffs and Trade. ☐

High-tech Exports Outpacing Imports

U.S. exports of advanced technology products, such as those in biotechnology, computer, and aerospace areas, exceeded imports of similar products by $25.5 billion in 1989, according to the U.S. Dept. of Commerce.

This is the third straight year in which trade surpluses have exceeded $20 billion in this category.

The large surplus is mostly the result of continuing U.S. dominance in aerospace products. Seattle-based

R&D NEWS

Researchers Defy Drug Testing

While many U.S. companies are jumping on the drug-testing bandwagon, the majority of researchers who responded to *R&D Magazine's* October Drug Testing Poll say they never have been screened by their employers for the use of illegal drugs.

Of the 115 researchers who responded to the *R&D* poll, 74% say they have never been tested for drug use before or during their employment.

Only 43% agree that their employers should screen coworkers for illegal drug use. This contrasts sharply with a 1990 Gallup poll of 506 workers in Illinois, which is ranked among the worst states in the nation for reported on-the-job drug use. Nearly 70% of the Gallup respondents said their companies should adopt drug testing programs.

While 66% of *R&D's* respondents believe law enforcement officers, air traffic controllers, and health care professionals should submit to drug tests, 51% of the researchers say they are offended by such random testing in their own profession. Nearly half of these respondents argue that the practice violates employee civil rights.

"Drug testing is a bio-invasive procedure that, if implemented anywhere, will ultimately result in a loss of our freedoms everywhere," writes one researcher.

Some say they would look for employment elsewhere if asked to submit to drug tests.

"When I graduated with my bachelor's degree in December 1990, I went job hunting in the Chicago area and I landed an interview with a large health care company," writes one *R&D* respondent. "I was shocked to learn that before the interview, before even filling out an application, I was handed a form explaining their drug testing policies and asked to sign away my constitutional rights. I told the secretary I would not do that for any job.

"Evidently, my response surprised her because she immediately called for the head of the personnel department. I explained my position to her and she admitted that in all her 12 years of experience, no one had ever even issued a word of protest to the policy. Now it was my turn to be totally shocked!"

Still, 49 of the 115 *R&D* respondents advocate mandatory drug testing for research professionals and say they would be willing to sacrifice a bit of personal freedom to ensure that they were working in a drug-free laboratory.

"The overruling fact in this controversy is that safety, both public and personal, must win out over 'civil rights,'" writes one researcher in favor of drug testing.

Another offers a more sobering response: "I believed drug testing violated my civil rights—until I stopped using drugs!"

Some researchers said they felt their employers had an obligation to screen employees for illicit drug use. "I believe an employer should be able to test employees for drugs that alter their ability to work properly," says one university professor. "While my employment is not in a critical area, I would welcome employer-paid testing of our whole faculty to prove that the workplace is drug free."

Compared to workplaces of the Gallup poll respondents—nearly 40% say they have seen or heard of others using drugs on the job—the labs of *R&D* respondents seem to be relatively drug-free. Still, 23%—about one in four—say they know a coworker who uses illegal drugs.

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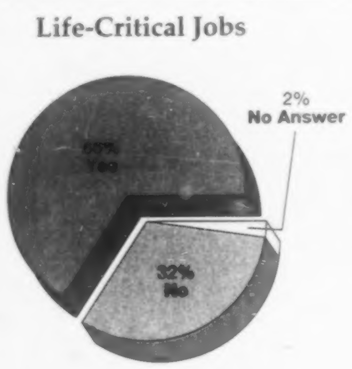
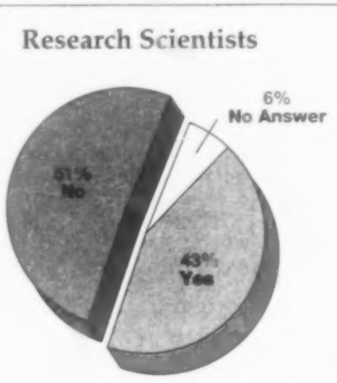
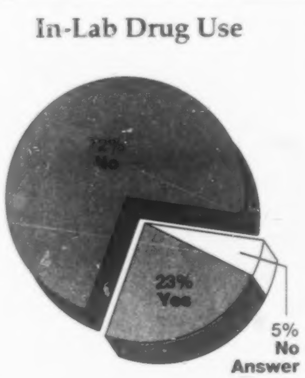


Should there be drug testing of pilots, police officers, physicians, and others in life-critical occupations?



Should there be drug testing of research scientists?



Do you know of any employee at your organization who uses illegal drugs?

Some researchers who report drug use in the laboratory say that the practice doesn't always compromise worker safety.

"I know of more than one [computer programmer] who is more creative . . . when a little high," writes one respondent. "Drugs can turn mundane logic into unique and creative thinking."

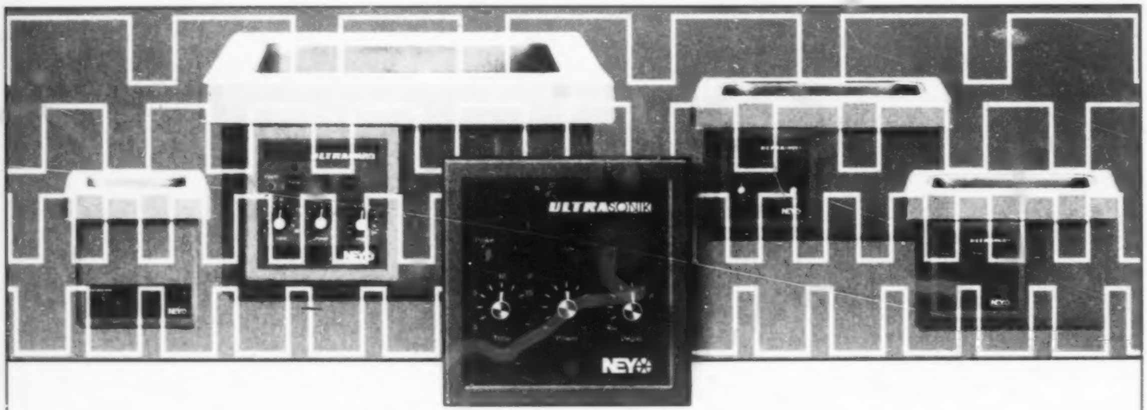
Those who have not witnessed drug use in their laboratories find even fewer reasons for their employers to implement drug testing programs.

"Drug testing in the workplace has become increasingly commonplace over the last few years, and it's long past time for some serious reflection," writes one scientist. "As researchers, we should all ask ourselves whether the state of scientific research has improved as a result of drug testing.

"As I examine the scientific literature in my daily work, I find no evidence that the quality or quantity of scientific research has increased during the last few years, as drug testing has become more prevalent.

"Our employers are not the police, and they should not be expected to act as such by the Federal government. If drug laws cannot be enforced by techniques that maintain the inalienable right to privacy of the individual in our society, then these laws should be repealed." ☐

News continues



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CONCENTRATE
Polaroid
simple green
ALL-PURPOSE SCRUBBER
JUST ADD FRESH OR S

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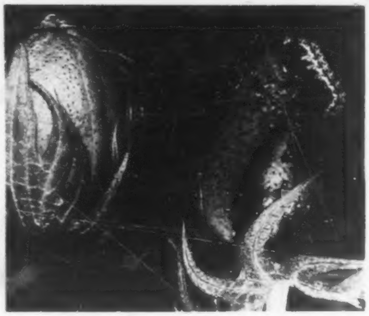

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ABOUT THE COVER These environmentally responsible products are evidence of a burgeoning "green" revolution. For more about this revolution and the mixed reviews it is receiving, turn to page 32. *Photo by Jack Grossman, Images Photographics Inc.; shot at Sandoz Crop Protection, Des Plaines, IL.*

R&D

The International Magazine of Research and Development

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Smart companies are realizing that to be successful in the 1990s, you must develop products with the environment in mind.

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Supercritical fluid extraction offers a nontoxic alternative to conventional techniques. Will it work for you?

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Computer image analysis systems are getting more diverse every day. Here are today's trends, plus a dozen shopping tips.

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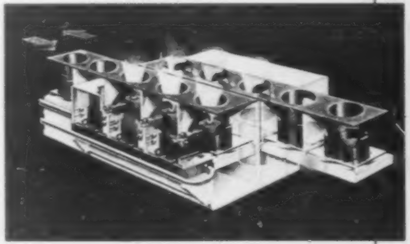
The link between thin-film deposition processes and characterization methods creates stronger wear coatings and denser magnetic films.



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Here's a New Benchtop LC/MS 61

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R&D BUSINESS

Instruments Continue Growth in 1991

Exports are expected to fuel most of the 3.7% total growth (in constant dollars) in laboratory instrument shipments in 1991, says the U.S. Dept. of Commerce (DOC) in its *1991 U.S. Industrial Outlook.* This builds upon the 2.6% growth that instrument manufacturers experienced from 1989 to 1990.

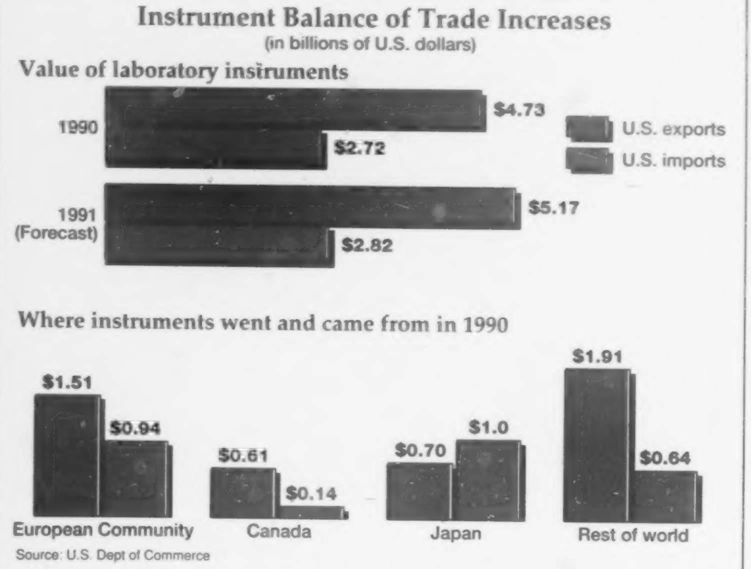
This category includes analytical and optical instruments, laboratory apparatus, and mechanical testing equipment.

"The forecast is based on moderate economic growth in the U.S., increased industrial investments, and increased government R&D," says Lewis Podolske, an industry specialist at the DOC's Office of Microelectronics and Instrumentation, Washington, DC. The forecast takes into account the current U.S. recession, but was made before the January hostilities in Iraq.

Countries in the European Community were the main destination of U.S. instrument exporters, while imports from Japan exceeded exports to Japan by $312 million. However, imports from Japan actually dropped 6% in 1990 to $1.01 billion from $1.07 billion in 1989.

Most of the instrument growth is the result of continued growth in pharmaceutical, food processing, biotechnology, environmental monitoring, and materials research industries. More instruments are being sold to government labs with large research projects than to those with smaller programs, according to Podolske.

—*Tim Studt*



Source: U.S. Dept of Commerce

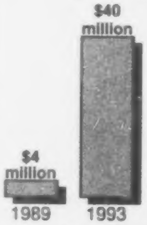
Exports of U.S. laboratory instruments *will increase faster than imports in 1991, further boosting the already positive trade balance by more than $300 million.*

Diamond Business Getting Competitive

"The U.S. has pretty much followed [Japan] in the application of diamond-film technology for the past 10 years," says Edward Peters, a senior scientist at Arthur D. Little Inc., Cambridge, MA. "But within the past year, U.S. companies [have started] to move that technology forward."

There are several U.S. firms that now offer diamond coating services for other firms, so users can evaluate the advantages of diamond coatings on their own products without having to develop the coating process from scratch, says Peters. Most of these coating firms have been in business for several years and are associated with university research centers. ☐

SFE Growth Fueled By Cost Savings



Savings in analysis time and labor with supercritical fluid extraction (SFE) systems will cause this market to increase 10-fold by 1993 from its 1989 level, according to a forecast by Strategic Directions International Inc., a Los-Angeles-based management consulting firm.

SFE is a sample-preparation technique that is used to isolate specific materials from its analyte through the use of supercritical fluids. For more on SFE, see article in this issue.

Lederman Calls for More R&D Funds

Low morale among academic researchers is a serious concern for U.S. long-term interests, says Leon Lederman, president-elect of the Washington, DC-based American Association for the Advancement of Science, in a recently completed survey of 250 university scientists.

"The source of the low morale appeared in letter after letter—lack of funding," says Lederman.

Lederman cites several reasons why there is less real dollar R&D support today than was available 20 years ago, including higher equipment costs, higher regulation costs, higher administrative costs, and Federal support that has not matched growth in the number of researchers.

Lederman proposes that doubling of Federal funding for academic research to $10 billion would bring the U.S. to 1968 levels. ☐

R&D NEWS

Drug Firms Hit With New FDA Regulations

Facing increased pressures from several directions, U.S. pharmaceutical manufacturers have encountered yet another hurdle in their challenge to comply with new regulations from the Food and Drug Administration (FDA).

Last October, the FDA implemented a new pre-approval and inspection program to guarantee that generic and research-based drug companies are complying with Good Manufacturing Practices (GMP).

The goal of these New Drug Application guidelines is to assure that the bio-batch submitted with the application actually matches the products being manufactured.

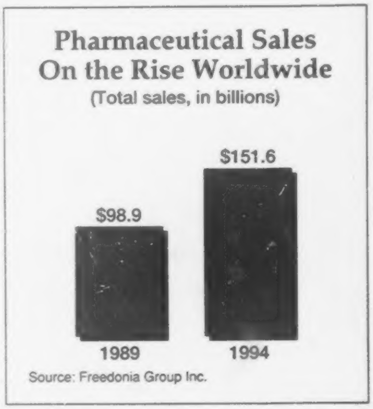
"Hopefully, this new program will not result in any further delays in the approval of new drugs," says Jeff Trewhitt, spokesman for the Pharmaceutical Manufacturers Assn., Washington, DC.

Trewhitt says that in 1989, the average new drug application review time for brand-name drugs was 32.5 months. The average for 1990 was 27.7 months. "This is a step in the right direction, but still well above the six-month statutory standard," he says. "We would hate to see a setback at this crucial time."

Over the past five years, R&D costs have skyrocketed while the number of new drug approvals has remained constant, according to industry sources. On average, of 20 drugs entering the final testing stage, only one will be approved for market.

The high cost of bringing drugs to market, the need for increased automation in production, and the constraints in the laboratory environment all combine to impact severely on daily operations.

"The pharmaceutical industry is under increased regulatory pressure to certify that a company's analytical instruments, data systems, and laboratory information systems provide accurate and reliable results," says Laura Lauman, marketing manager for Perkin-Elmer Corp., Norwalk, CT.


Pharmaceutical Sales On the Rise Worldwide
(Total sales, in billions)

Source: Freedonia Group Inc.

***Demand for** medical products worldwide will grow 9% annually to more than $235 billion by 1994, according to the Freedonia Group, Cleveland. Of this estimated total, pharmaceuticals will be $152 billion.*

The FDA is concerned with validation of methods to ensure that reproducible and reliable test results are obtained. The agency oversees the calibration of instruments, equipment logs and maintenance schedules, and documentation systems.

The agency is particularly concerned that pharmaceutical companies can show that data have not been altered. "We and other instrument makers are designing data storage systems to encode data and make it unavailable to the user in its primary state, so that it cannot be altered from that point on," says a spokesman for Shimadzu Scientific Instruments, Columbia, MD. "Everyone is attempting to follow Good Laboratory Practices. However, computers have not been around as long as other equipment, and software is still evolving to deal with this situation."

—Howard Goldner

***Technicians at Genentech** assemble final packaging and apply labeling to pharmaceutical products.*

SOFTWARE

Data Visualization

Dynamic data visualization and management on a new, higher level of complexity is possible with Data Views release 8.0 for all major UNIX and VMS workstations. Added features include image rotation, scaling, and motion along a path.
V.I. Corp. **Circle 453**

Math Assistant on Disk

Derive version 2.0 is a productivity tool for use with DOS 2.1 or later by scientists, engineers, and educators. An expert system, it combines computer algebra with a menu-driven interface to solve a wide range of complex math problems.
Soft Warehouse **Circle 454**

Elastomer Selection Guide

The "3M Elastomer Selection and Design Guide" is specifically intended to help design and materials engineers and rubber processors choose the best elastomers or fluoropolymers for specific applications. Available in 5.25-in. or 3.5-in. disk formats, the easy-to-use, menu-driven program requires little computer skill.
3M Co. **Circle 447**

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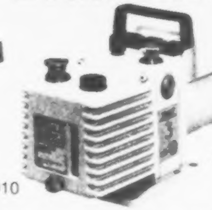

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Fluorescence Spectroscopy: Chances are, it belongs in your lab

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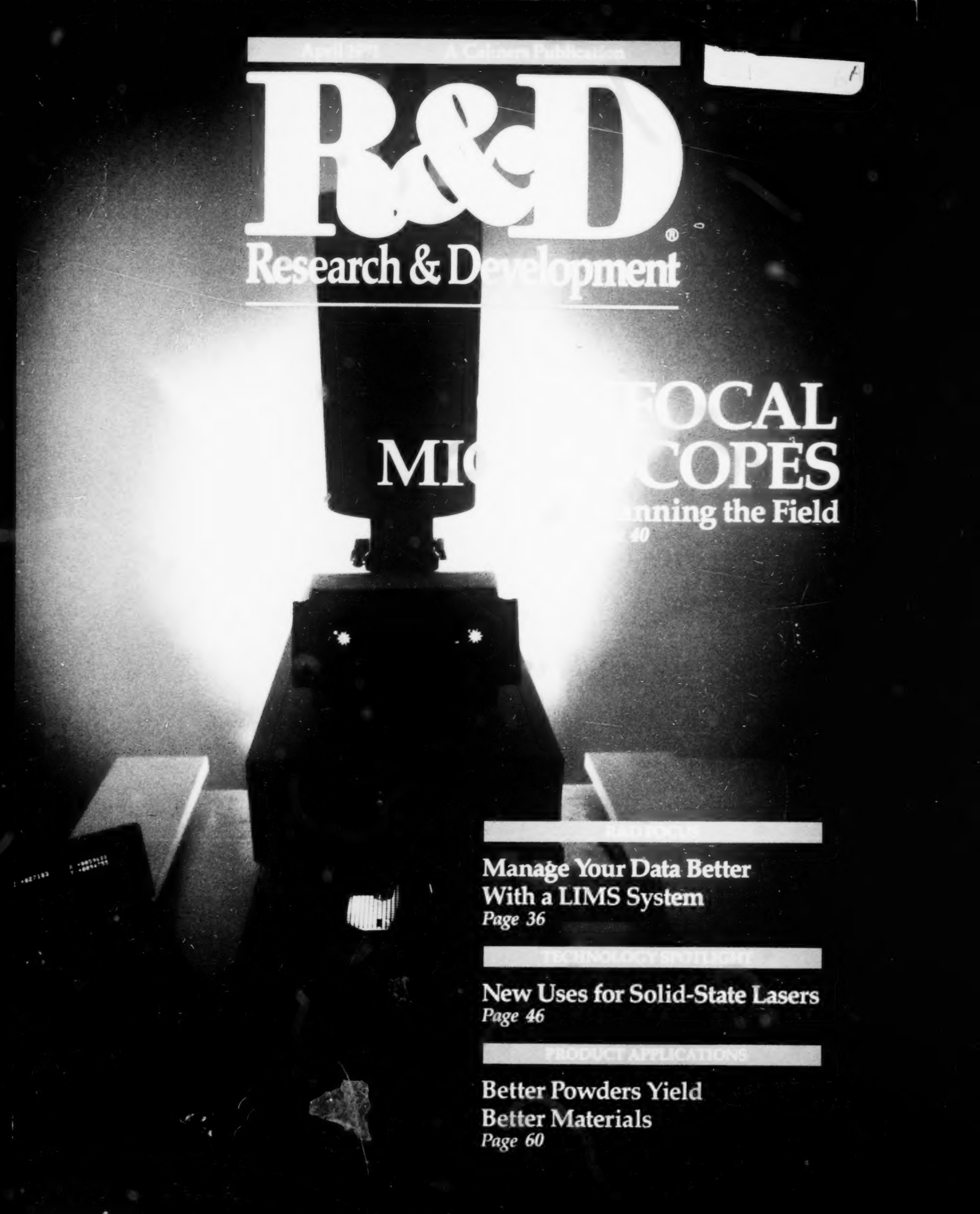

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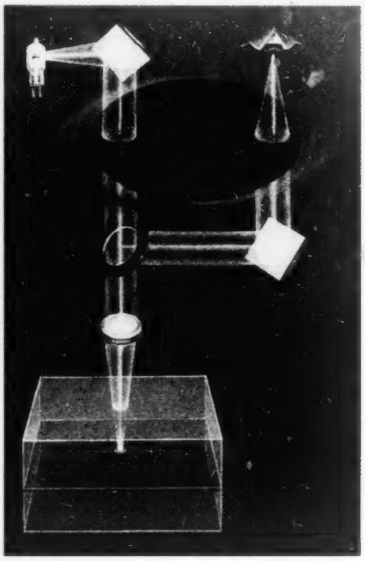

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ABOUT THE COVER Confocal microscopes let users analyze samples in three dimensions. See story page 40. *Photo: Technical Instrument Co.*

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R&D requirements to measure temperatures over 1000 C are driving advances in contact and noncontact instrumentation.

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Easy real-time processing of data from a variety of instruments can justify the cost of a laboratory information management system.

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Confocal Microscopes 40

Confocal microscopes yield a series of high-resolution, high-contrast images that can be reassembled into a 3-D picture.

Solid-State Lasers Generate Even More Applications 46

Increases in efficiency and power have led to solid-state lasers being used in medical and material processing areas.

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Marine scientists are using a relational database management system to sort through data collected at different times and locations.

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Improved Powder Processing Creates Better Materials 60

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Combining ESCA With SSIMS 65

SSIMS and ESCA enhance each other's ability to solve problems.

R&D BUSINESS

Struggling With Low Demand, Computer Firms Become More Competitive

Many U.S. computer firms are being restructured following last year's modest 8.4% production increase, the smallest annual increase since 1975. However, Japanese computer firms are increasing their capabilities for both hardware and software products.

One way Japanese firms are attempting to offset lower demand is by expanding into European markets, traditionally a U.S. stronghold. To establish a foothold in 1990, Mitsubishi Electric purchased Apricot Computers, a UK PC manufacturer, and Fujitsu bought Britain's International Computers firm. Several Japanese firms have announced plans to market new laptop products in Europe, their current market share leader.

Longer-term capabilities are being established by increasing technical prowess. Fujitsu recently announced plans for building a 400,000-m^2 R&D complex for communication, semiconductor, and computer products, and another center for software development, both in Chiba, Japan, according to a report by Nihon Keizai Shimbun, a Japanese publishing firm.

IBM will more than double its Japanese systems integration subsidiary this year, reflecting its increasing development of hardware and software.

"IBM is looking very carefully at its expenses, but we are sustaining our R&D investment," says Marc Brodsky, director of the technical staff at IBM's Research Center, Yorktown Heights, NY. "It's hard to compare IBM's investment to that of Japanese firms because they have so many subsidiaries."

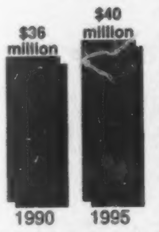
Software is another area where Japanese firms are expected to increase their penetration, according to Michael Cusumano, author of the *Japanese Software Factories.*

Fujitsu, NEC, Hitachi, and Toshiba all have established "factories" with thousands of programmers writing software for consumer and industrial products.

"I don't feel that the factory model is the most efficient way to create software," says Brodsky. "We have had examples of improved software productivity and quality by concentrating on the methodology involved in its creation."

The short-term outlook for computer firms is not bright, with only a 6.9% increase forecast for 1991, according to Cahners Economics, Newton, MA. Cahners economists forecast that demand will rebound in 1992 with a 15.2% increase. —*Tim Studt*

High Costs Limit Growth for ESCA

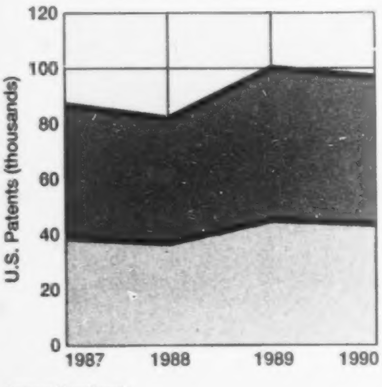


Worldwide demand for electron spectroscopy for chemical analysis (ESCA) instruments is forecast to grow about 2% annually to $40 million in 1995, according to Strategic Directions Intl., a Los Angeles-based management consulting firm.

The slow growth is caused by ESCA's high initial cost and low replacement rate. ESCA is used for surface analysis applications, such as in the detection of material impurities.

U.S. Patent Distribution Levels Off As Foreign Inventors Lose Small Share

Foreign Share of U.S. Patents Levels Off



Source: MicroPatent

Foreigners Garner Top Patents

Mitsubishi	1,385
Hitachi	1,104
Fuji	1,089
Toshiba	1,010
Canon	927
General Electric	854
Eastman Kodak	735
U.S. Philips	669
IBM	653
Siemens	604

Source: MicroPatent

***The foreign share** of the 99,275 U.S. patents issued in 1990 has leveled off in the past two years, after increasing steadily over the past several decades.*

In 1990, for the second year in a row, U.S. inventors increased their share in the total number of U.S. patents received, according to a recent survey by MicroPatent, a New Haven, CT-based publisher of patent information.

Granted, the share increase was less than 0.1%, but until 1989, U.S. inventors had decreased their patent share every year since 1977. The 99,275 patents issued in calendar-1990 is down from 102,713 issued in 1989.

About 53.4%, or 53,046, of the patents awarded in 1990 went to U.S. citizens, while 46.6% went to inventors in foreign countries. In 1990, Japan continued to increase its share of U.S. patents, rising to about 21.6% from 21.1% in 1989.

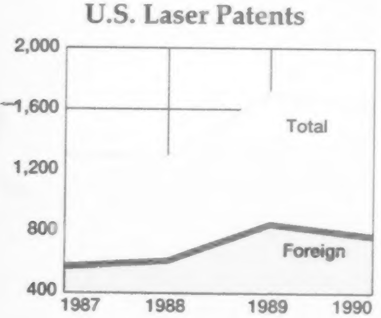
Mitsubishi, the large Tokyo-based industrial conglomerate, received the most patents with 1,385. The U.S. state with the largest number of awards was California with 7,945.

For more information, call 203/786-5500. **R&D**

Solid-State Lasers Generate Even More Applications

Increases in efficiency and power have led to solid-state lasers being used in medical and material processing areas.

By ***Tim Studt,*** *Senior Editor,* R&D Magazine



Organizations With the Most U.S. Patents

U.S. Government	70
Spectra-Physics	38
Mitsubishi Denki	38
Hitachi	35
AT&T	34
Hughes Aircraft	30
Canon	30
Ricoh	30
Eastman Kodak	28
Sharp	27

Source: MicroPatent

Foreign companies *account for almost half of all the U.S. laser patents issued every year, with five Japanese firms in the top 10 receiving the most patents.*

Lasers have become ubiquitous, involving all aspects of technology. The numbers of applications and laser products are both so great that it no longer is clear which technology drives the development of the other.

While there is continued strong demand for some of the older technology systems, such as dye- and gas-driven lasers, the major research emphasis now is on developing higher efficiency and higher power solid-state systems.

The high power, broad tunability, and solid-state convenience of titanium-sapphire lasers, for example, continue to attract researchers. Ti-sapphire lasers have been even more successful than many manufacturers expected.

"Many scientists bought Ti-sapphire lasers for their IR and near-IR wavelengths," says Mark Sobey, a product manager for Spectra-Physics, Mountain View, CA. "They hadn't used these wavelengths before, because of issues associated with IR dye lasers."

The recent availability of modelocked Ti-sapphire lasers has created even more interest. Modelocking is the locking together of the longitudinal modes of a laser, so it can oscillate in-phase on all of the modes. Modelocked pulses are very short, but have high peak power levels.

Modelocking of Ti-sapphire lasers has been obtained in a passive technique by inserting an optical element in the laser cavity, according to Colin Seaton, solid-state product manager at Coherent Inc., Palo Alto, CA.

Active or regenerative modelocking also has been obtained by tapping a signal off the laser cavity with a photodiode and feeding the photodiode's output back into the drive frequency of the Ti-sapphire laser.

"This allows the modelocker and the cavity to always stay on resonance, regardless of cavity length changes or frequency changes," says Mark Sobey, product manager at Spectra-Physics, Mountain View, CA.

Currently available products can supply more than 1 W of power in 2 psec transform-limited pulses. Prototype systems have been demonstrated with pulses that are less than 100 fsec long.

"With standard wavelength optics, you also should be able to obtain short pulses at wavelengths of about 1,000 nm," says Sobey.

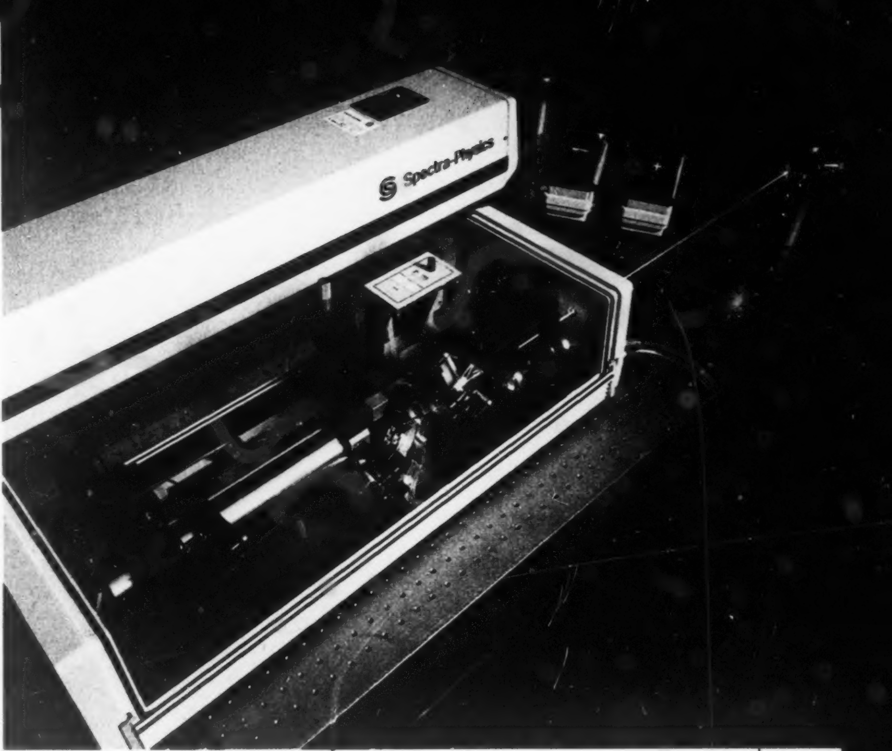
The short pulses of modelocked Ti-sapphire lasers are perfectly matched for applications involving response times on GaAs semiconductors, which have bandgaps in the 800- to 900-nm range.

"The high powers in the IR also allow you to frequency double efficiently to about 350 to 500 nm with an output of 300 to 400 mW," says Sobey.

This is important because the energy contained in each photon of light in the blue or UV range is higher than in the red or orange ranges, thereby enabling chemists to obtain higher sensitivities in many biochemical spectroscopic applications.

"Diode arrays will be widely used for pumping solid-state lasers," forecasts James Davis, associate director for laser R&D at Lawrence Livermore (CA) National Laboratory (LLNL).

AlGaAs semiconductor diode arrays are used to pump high-power, solid-state lasers (see accompanying photo). Devices with peak powers of 1.5 kW and an average power of nearly 1 kW emitting from an aperture of about 4 cm^2 already have been fabricated.



Modelocked titanium-sapphire lasers *can be tuned from 720 to 840 nm and supply more than 1 W average power with transform-limited pulses less than 2 psec in length.*

Diode arrays can be used to pump solid-state lasers for cutting, welding, drilling, and weapon development, according to Davis. "There even are concepts for diode pumped lasers for a fusion power system," he says.

At the other end of the power scale, researchers at IBM's Zurich (Switzerland) Research Laboratory recently announced a development in extremely small AlGaAs semiconductor diode lasers. The IBM researchers were able to repeatedly fabricate 20,000 of these lasers on a 2-in.-dia semiconductor wafer. These devices can be integrated with other electronic components on optoelectronic chips, thereby using both light and electric current to carry information.

LLNL researchers also recently developed two new chromium-doped materials for laser media—$LiCaAlF_6$ and $LiSrAlF_6$. "These materials are similar to what you get with Ti-sapphire materials: very broad bandwidths and tunability in the near-IR," says Davis.

But these materials have better thermal characteristics than Ti-sapphire crystals, indicating they might have use in high-power applications.

There also is additional development in upconversion lasers, or solid-state lasers that emit in the visible region without the need for harmonic converters or doubling crystals.

"We're pushing toward upconversion lasers that operate at room temperature, since most of the current products operate at liquid nitrogen temperatures, such as the blue upconversion thulium system we developed last year," says Dennis Gill, deputy division leader of the Chemical and Laser Sciences Div. at Los Alamos (NM) National Laboratory.

We currently have developed an upconversion laser with two different diode pump frequencies that, depending upon the combination of the pump lights, allows you to get three different colors of light out of the laser, or combinations of those three," says Gill.

The recent explosion in applications of lasers has provided the impetus for continued development of these new systems.

Nowhere else is this as much in evidence as in the medical surgery area.

Peter Lee (left), a GM researcher, *and Brad Hare of Laser Photonics developed this diode laser spectrometer to study air pollutants, but also use it as a breath analysis instrument to study diabetes.*

"Laparoscopic cholecystectomy, or laser-based removal of the gall bladder without the need to open the abdominal wall, has swept the medical industry in the past year," says Irving "Skip" Arons, a medical laser consultant at Arthur D. Little Co., Cambridge, MA.

This surgery is performed by inserting surgical instruments and a small video camera (laparoscope) through four puncture sites. The internal cutting, coagulating, and evaporating of the gall bladder generally is performed with laser light transmitted through a disposable fiber delivery system from a Nd:YAG source.

The advantages of medical lasers have been talked about for many years, but the lack of a significantly large number of successful procedures has limited acceptance by both patient and surgeon.

"The one technique that might have taken off was laser angioplasty to remove coronary inclusions," says Arons. "But it didn't happen because the laser's results were not any better than those using balloons."

The timing and technology for laproscopic cholecystectomy were better. In this procedure, the laser reduces the cost of the operation by half and takes a third less time to perform. But the big advantage is the reduced trauma that the patient incurs. Patients now can return to work in three to seven days, compared to the four

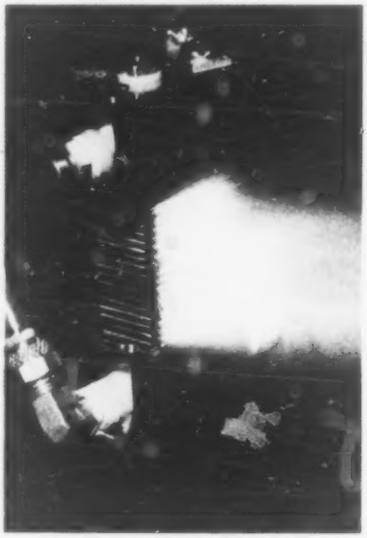
'Diode lasers will be widely used to pump high-power, solid-state lasers,' forecasts Livermore's Davis.

to six weeks that a conventional surgical procedure required.

About 10% of the more than 500,000 cholecystectomies in 1990 were performed with a laser. A report by Samuel Navarro, a financial analyst with Needam & Co., New York, forecasts that ratio will rise to 80% by 1995. The market for laser delivery systems for these procedures is predicted to increase from $30 million in 1990 to more than $140 million by 1995, says Navarro.

Other surgical procedures where lasers provide clear-cut clinical benefits include appendectomies, hernia repairs, bowel resections, vagotomies, abdominal hysterectomies, prostatectomies, arthroscopic surgery, angioplasty (with new wavelength lasers), dentistry, and corneal sculpting.

Corneal sculpting is expected to receive U.S. Food & Drug Administration approval by 1994, says Arons. Phoenix Laser Systems, San Francisco, recently received FDA approval for a frequency-doubled Nd:YAG surgical workstation used to correct post-cataract complications.



This AlGaAs semiconductor *diode array has a peak power of 1.5 kW and an average power of nearly 1 kW emitting from a 4 cm² aperture, enabling it to pump high-power, solid-state lasers.*

This system uses a computer imaging, tracking, and stabilization system to preprogram a pattern of laser pulses where the surgeon wants to cut or remove ocular tissue. The cataract procedure is one of 11 standardized ophthalmic surgery procedures that Phoenix expects to have qualified over the next several years.

Laser processing of materials also has progressed beyond the traditional cutting and welding applications to more advanced surface processing techniques. These techniques include surface heating, melting, vaporizing, vapor deposition, and brazing.

Researchers at Northwestern University's Basic Industry Research Laboratory, Evanston, IL, for example, use a laser to seal pores in a plasma-deposited Al_2O_3 coating and homogenize the surface microstructure. This surface glazing improves the wear, erosion, and corrosion resistance of a material's surface.

Integration and automation of these surface treatment processes will allow users to optimize surface coatings for specific applications. **R&D**

Big Research Bucks for Big Research Lasers

Federal agencies are forecast to increase their research spending on laser systems by more than 17% annually over the next four years, to $2.2 billion in 1995, according to Foresight Science & Technology, a market research firm in Port Townsend, WA.

About 65% of this funding will be spent on defense items, such as IR detectors and fly-by-wire avionics.

Green-yellow light *from copper-vapor lasers is used to pump dye lasers which produce tunable, high-power light for enriching uranium fuel.*

The atomic vapor laser isotope separation (AVLIS) and inertial confinement fusion (ICF) programs at Lawrence Livermore (CA) National Laboratory (LLNL) together account for nearly $200 million in the FY91 Federal budget.

Despite other recent budget cutting announcements, AVLIS, a uranium-enrichment process, is on schedule for a late-1992, full-scale demonstration, according to Ron Cochran, deputy associate director for lasers at LLNL. Results of this demonstration will determine the status of full-production facilities.

"From the long-term standpoint, however, the U.S. Department of Energy would like a private company to handle AVLIS," says Cochran.

The ICF program involves upgrading LLNL's 100-kJ Nova laser to roughly 2 MJ at a cost of up to $400 million, spread out over the next five to 10 years. Most commercial spinoffs from the upgrade will be in better laser components, such as beam splitters, polarizers, optical coatings, and high-power switches.

Laser Companies

For more information on laser systems and components, circle the appropriate numbers on the Reader Service Card.

Space limitations preclude listing all manufacturers of this equipment. For further information, see the *R&D Magazine* Product Source under "Lasers."

Ti-sapphire	
Coherent	**618**
Excel	**619**
Lexel	**620**
Schwartz Electro-Optics	**621**
Spectra-Physics	**622**
Medical	
Candela	**623**
Laser Photonics	**624**
Laserscope	**625**
Surgical Laser Technologies	**626**

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High **492** Medium **493** Low **494**

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Automate and Enhance Old IR/UV Spectrometers

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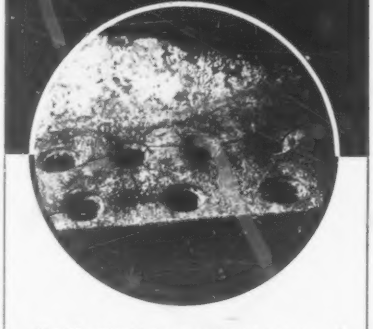

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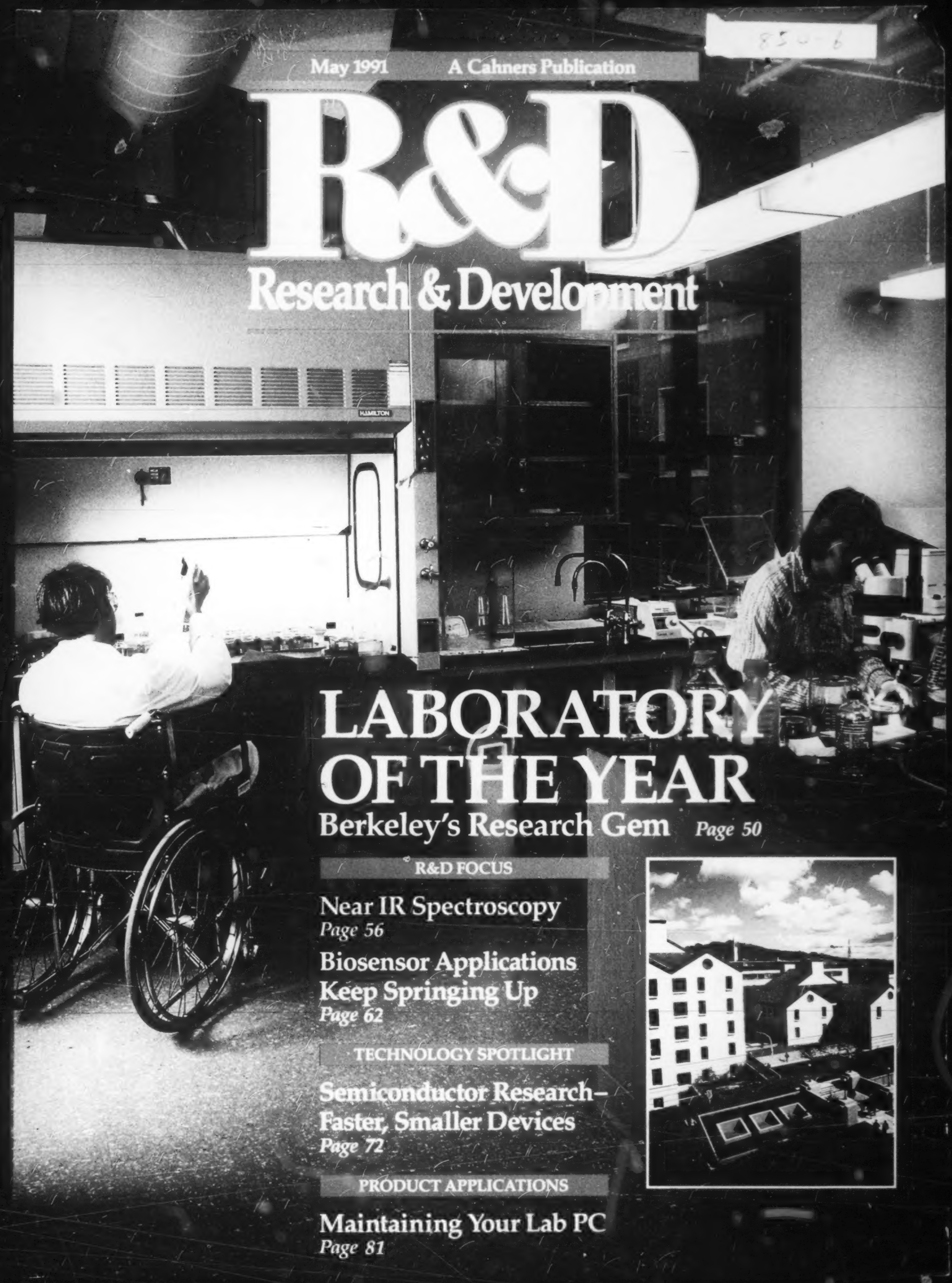

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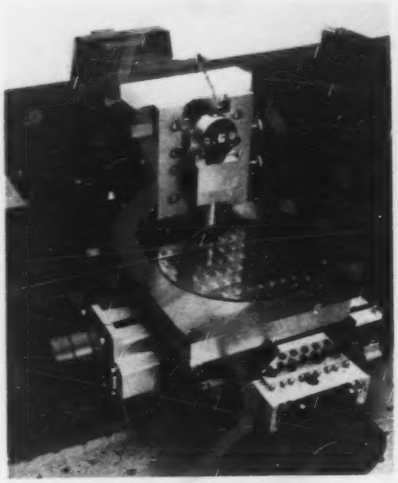

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R&D BUSINESS

Researchers' Salaries Increase as Slow Drug Firm Growth Forces More Restructuring

The average industrial pharmaceutical scientist received a 3.4% salary increase in 1989 to $63,200, according to a recent survey by the American Association of Pharmaceutical Scientists, Alexandria, VA.

While the overall average increase failed to match 1989's 4.8% inflation rate, some individual statistics were more encouraging, such as the 15.9% increase to $44,500 for the starting salaries of pharmaceutical researchers right out of school and the 16.1% increase to $66,900 for researchers holding a PharmD degree.

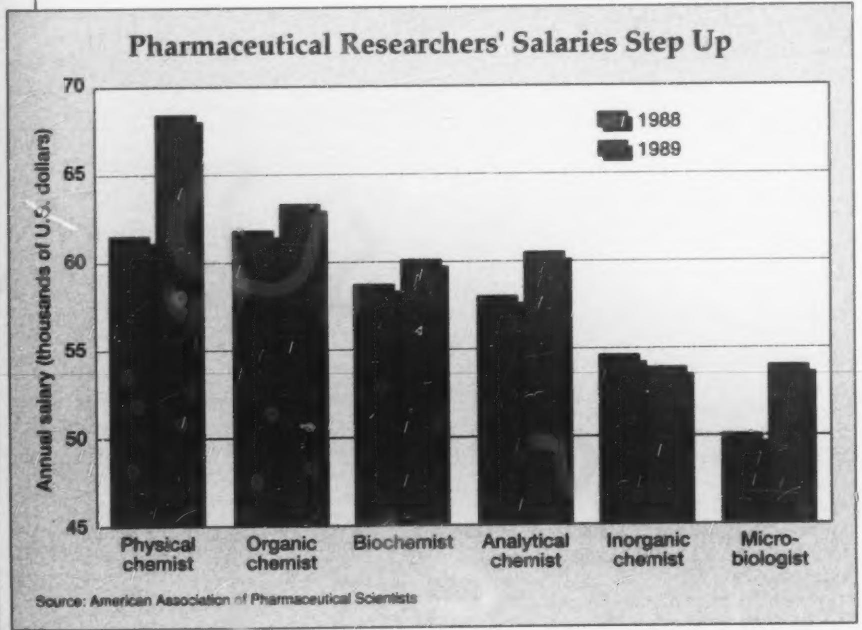
Industrial researchers received higher average salaries than those in colleges and universities ($58,800) and those in government laboratories ($54,400). Industrial researchers also received an average of $11,100 in supplemental income from their employers in 1989.

The salary increases for university (6.5%) and government (6%) pharmaceutical scientists exceeded those of their industrial counterparts. Restructuring of the pharmaceutical industry was at least partially responsible for holding down industrial increases.

"The pharmaceutical industry as a whole is strong," says Mason Irving, manager of Arthur D. Little's Health Care Practice. However, profits from existing drugs are slowing, with fewer new drug prospects in the pipeline.

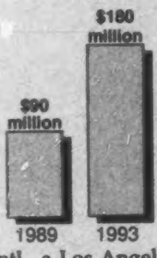
With slower revenue growth and increasing development costs, pharmaceutical firms are looking at new ways to develop drugs. In many cases, the bigger-is-better route is being taken, such as Merck's joint venture with DuPont in 1990.

In other cases, buyouts of biotech firms and large pharmaceutical firms are occurring to marry the best of both worlds, such as Roche's buyout of Genentech. "To be a major player in the pharmaceutical industry, your product line has to be liberally sprinkled with products from both the traditional sciences and biotechnology," says Irwin Lerner, president of Hoffman-La Roche, Nutley, NJ. ☐



Average salary for pharmaceutical scientists in industry rose 3.4% in 1989 to $63,200, $4,400 to $8,800 more than university and government scientists received.

Agriculture Driving Growth in Near IR



The market for near infrared (NIR) spectrophotometers is forecast to grow nearly 18% annually to $180 million in 1993, according to Strategic Directions Intl., a Los Angeles-based management consulting firm.

The most common applications for NIR instruments are in the agriculture and food industries. Its high growth is attributed to its efficiency and time-savings over LC and GC.

Israeli Government Offers Financial R&D Incentives

The Government of Israel is offering financial incentives to foreign investors in an effort to create jobs for the million Soviet immigrants expected in Israel over the next four years.

Approved ventures can receive up to 66% of the costs for an R&D project and the ability to depreciate 100% of the price of new equipment within one year. Investors also can obtain cash grants for up to 38% of the fixed asset costs, or government guarantees covering two-thirds of the total value of the investment.

For more information, call Govt. of Israel Investment Authority, New York. 212/560-0630. ☐

Bilingual Demand Rising for Graduates

Companies are increasingly looking for—and finding—graduating technical professionals who are bilingual, according to Howard Wakeland, associate dean of the college of engineering at the Univ. of Illinois, Urbana.

"About a quarter of the companies that interview our students are looking for international characteristics, as well as a strong engineering background," he says. "And they're finding good candidates because most of the better technical schools are enrolling students that have had two to four years of high school languages.

"The number of students taking a foreign language in our school has increased fourfold in the past 10 years," says Wakeland. "About 40% of our graduates have a reasonable capability in a second language."

Foreign companies also are interested in bilingual students, according to Wakeland. Japanese firms have shown an interest in U.S. graduates that could work in Japan for a length of time and then come back and manage a Japanese-owned production facility in the U.S. ☐

Recession Hurts Growth of Advanced Composite Materials

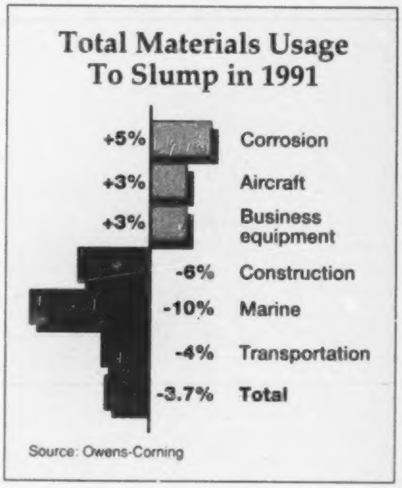
The current recession has hurt many industries that use advanced composite materials, especially construction, transportation, and marine industries, according to Patrick Moore, vice president of reinforcement materials, Owens-Corning Fiberglas, Toledo, OH. He forecasts a 3.7% decline in 1991 shipments from 1990 shipments, which were 3% lower than 1989 shipments.

Moore bases this and other forecasts on a number of key indicators, including a 0.8% decrease in the Industrial Production Index for Manufacturing Durables, an 8.8% drop in new housing starts, a 4.2% decrease in auto production, 4.1% inflation, and 6.4% unemployment.

"We expect this slowdown to continue through most of 1991," Moore says. He also notes that the composites industry has consistently rebounded from previous recessions.

The economic slowdown is not slowing down the development of new composite products. "We are continuing to introduce new products that will work to open up new markets," says Moore. Owens-Corning expects to introduce new products for the corrosion, business equipment, construction, and automotive markets. Aircraft firms have a large backlog of orders, however, this is a relatively small market for fiberglass composites.

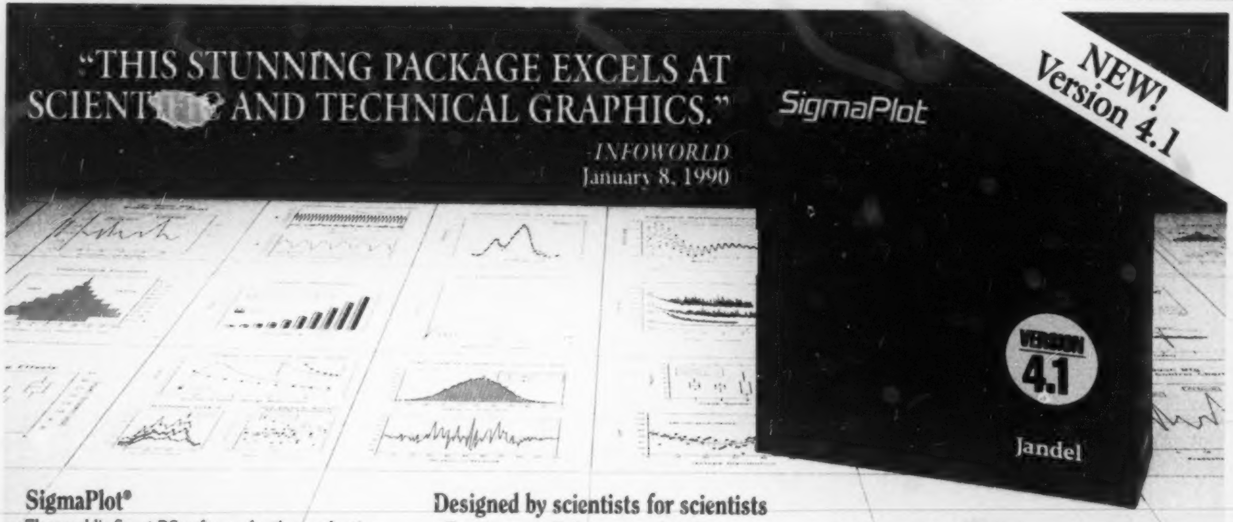
Recently passed U.S. Environmental Protection Agency regulations requiring the replacement of many existing storage systems will support new product development for the corrosion industry. Moore forecasts sales to the corrosion industry to increase 5% in 1991, following a 5% decline in 1990 from 1989 levels. **R&D**



Total Materials Usage To Slump in 1991

Source: Owens-Corning

***Small increases** in corrosion and aerospace markets for fiberglass-reinforced composites won't be enough to offset decreases in other big volume areas.*



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R&D NEWS

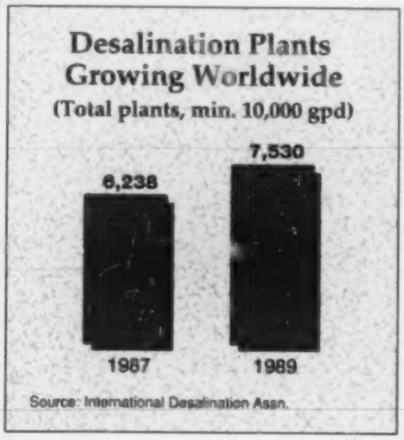
Improved Techniques May Boost Desalination

Interest in desalination techniques is heating up in the U.S. as drought-stricken areas of California and other regions struggle—and often fail—to maintain adequate supplies of potable water.

Costs for the processes are still relatively high but have been decreasing. R&D into new membrane systems for reverse osmosis (RO) should bring costs down even more.

An example is a type of membrane produced by a new thermal-inversion process developed at the Lawrence Berkeley (CA) Laboratory (LBL). The microporous anisotropic polymer membranes have very closely controlled pore sizes and porosity gradients, which make RO more efficient, LBL researchers say.

Unlike commercially available membranes, those formed by this process are said to have a unique open pore structure that offers the ability to perform RO at a high volume processing rate.



***Desalination plants** averaged 9.9% annual growth in recent years and are still on the rise. The International Desalination Assn. expects major growth in California, Florida, and Middle Eastern nations.*

Tests are reported to show that the polymer working surface can be easily modified by reheating the surface and re-executing the appropriate temperature program on one face. A variety of polymers and solvents can be used in the process, researchers say.

Even more dramatic gains may result from R&D into ceramic membranes like those being studied by Marc Anderson's group at the Univ. of Wisconsin, Madison. The UWM approach deposits thin ceramic films with very small, carefully controlled pore sizes onto appropriate support structures.

Nanometer-sized particles are fused to form the membrane that may be either a pure form of ceramic or a mixture. Among the support materials being tested are sintered stainless steel, porous carbon, porous alumina tubing, glass beads, glass tubing, and glass capillary tubes.

Ceramic membranes offer several advantages, according to Anderson.

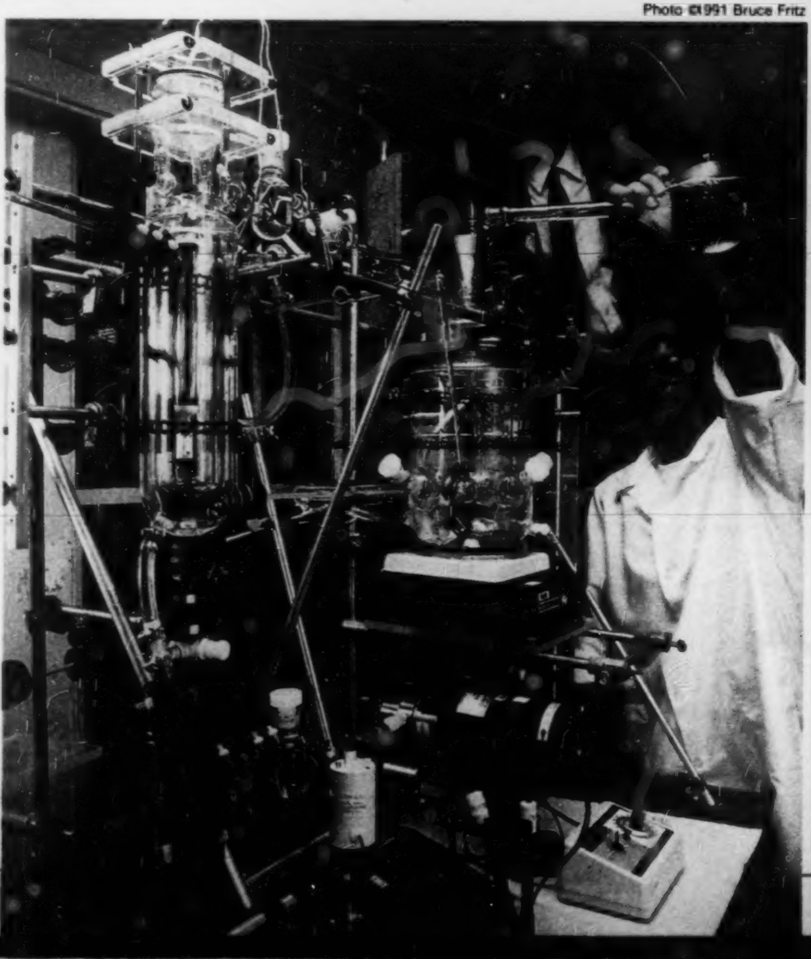
"All membranes foul and must be cleaned with chlorine bleach, but that's hard on cellulose acetate membranes," he says. "Ceramic membranes are resistant to such chemicals.

"Also, the efficiency of RO goes up with pressure. Ceramics can take much higher pressures and temperatures without failing."

Organic membranes must be replaced every one to three years, but ceramics could provide an "almost unlimited lifetime," Anderson says.

"The prospects for ceramics are good. We're preparing microporous metal oxides with pore sizes below 10 Å. This will let us take a fresh look at desalination." ☐

Photo ©1991 Bruce Fritz



***Ceramic membrane** research by the Univ. of Wisconsin, Madison's Marc Anderson (left) and research associate Jean-Pierre Kottelat has many possible applications, including reverse osmosis for desalination.*

Entrepreneurs at Heart

Want to run your own shop? You have lots of company, according to our Career Satisfaction Survey.

*By **Elizabeth Dougherty**, Contributing Editor,* R&D Magazine

Want to quit your job and become your own boss? You're not alone.

Although 93% of the more than 4,000 researchers who responded to *R&D Magazine's* first Career Satisfaction Survey do not own their own companies, more than a third (35%) would prefer to work for themselves rather than their current employers—or anyone else.

Three percent of the respondents already own their own companies, while another 4% own their own companies but also work for others.

Of the researchers who do not own their businesses, 42% are content to work for their current employers, in contrast to 23% who would opt for new employers. Fully 35%, however, would prefer to work for themselves.

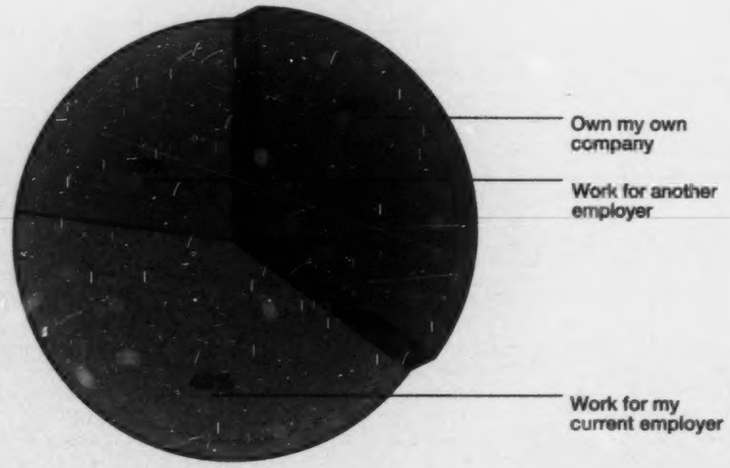
Many researchers who would prefer to work for themselves say their employers don't listen to their input, aren't interested in new ideas, and don't appreciate them.

"Upper management fails to listen and communicate with its employees," says an industrial engineer in his 30s working in Massachusetts.

In fact, 37% of the men who do not already own businesses say they would like to, vs. 18% of women.

"I find it frustrating that management is not willing to take an interest in new ideas," says one woman who would like to own her own business.

Employer Preferences



Of researchers who do not already own their own companies, more than a third would prefer to run their own shops, R&D's *Career Satisfaction Survey shows.*

A materials researcher in Ohio asks: "Why have a development department if the company has no interest in developing anything new?"

"The work is fun, but the rewards are insufficient," says T.V. Fingier, a senior engineer in League City, TX.

"Government projects and contractors are much too bureaucratic," says E.G. McKannan, a manager at Boeing, Huntsville, AL, who would rather own his own business. "They need more small businesses, small groups, and 'skunk-works.' "

A solid group of researchers in every income category, ranging from 34% to 37%, would rather own their own companies.

Approximately 36% of researchers under age 30 would prefer to own their own companies, as would 39% of those in their 30s. But from age 40 on up, the percentage of wishful entrepreneurs stabilizes at 33%.

Small entrepreneurial companies seem to attract employees who would like to make it on their own. The percentage of researchers who want to own their own companies is highest in organizations with fewer than 50 employees (45%). In organizations with 500 or more employees, only 33% want to strike out on their own.

Researchers with doctorates are the least likely to want to own their own businesses—only 30% would like to—while 40% of those with less than a bachelor's degree would like to do so.

Researchers who have fewer than 20 years' experience are most likely to desire owning their own companies. Of researchers with 5 to 14 years in their professions, 39% would like to do this, followed by 35% of those with 15 to 19 years' experience, and 34% of those with fewer than five years. At 20 years' experience and beyond, about a third of researchers who do not own their own businesses would like to.

Of researchers who have spent

Getting the Job Is the Easy Part, Survey Shows

Getting a foot in the door is not a problem for most researchers. Employers often track them down. Fully 29% of respondents to our career survey were recruited.

Researchers also found jobs by word of mouth (20%), newspaper or journal ads (20%), sending unsolicited resumes (15%), internships or summer jobs (4%), and other ways, such as company takeovers (12%).

The percentage of researchers who were recruited by their employers went up with such factors as age, education level, experience, and salary level.

For example, only 22% of researchers younger than 30 were recruited, compared with 27% of those in their 30s, 31% in their 40s, 33% in their 50s, and 34% of those 60 or older.

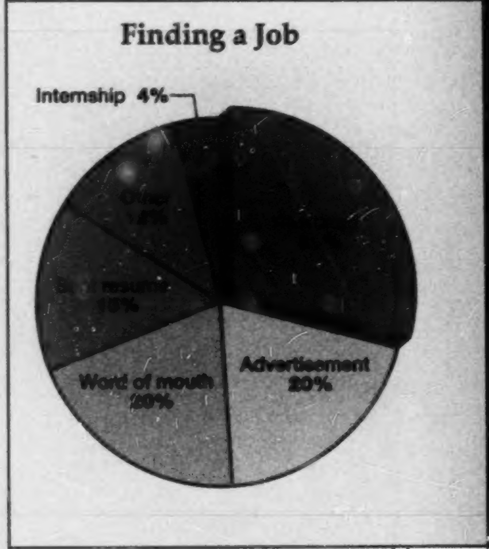
More than a third (37%) of researchers with doctorates were recruited, compared with 31% of researchers with master's degrees, 25% of those with bachelor's, and 21% of those with less than a bachelor's. Nearly a third of researchers with 15 or more years' experience were recruited.

Only 12% of those making between $20,000 and $29,999 were recruited. In contrast, employers recruited 44% of those making $70,000 or more.

Men (31%) are more likely to be recruited than women (20%). The percentage of researchers recruited in industry (32%) and universities (32%) is higher than that of researchers in government (24%) and consulting (22%).

Journal or newspaper ads were successful job routes for 24% of researchers younger than 40 and for 24% of female researchers. A quarter of the researchers with less than 15 years' experience found their jobs through ads.

Mid-sized companies successfully use advertisements to attract employees. The percentage of researchers working at organizations with 51 to 99 employees (27%) who found their jobs through ads edged out those who were recruited (26%).



Most researchers are recruited by their employers. Ads in newspapers and journals, word of mouth, and sending unsolicited resumes also have proved to be successful means of finding research jobs.

fewer than 15 years with their current employers, 38% would like to strike out on their own. This drops to 31% for researchers with 15 to 34 years' tenure and falls to 19% for those with 35 or more years' tenure.

Who actually takes the plunge? They're researchers like N.B. Proctor, a physicist who owns his own consulting firm in Texas.

"Being the owner is the only way to go in the U.S.A.," he says. "Big business and big government stifle productivity and innovation."

Of researchers who work solely for themselves, fully 60% are 50 years or older, 96% are male, 50% have 30 or more years' experience in their professions, and 69% have had four or more employers during their professional careers. More than half (57%) work in consulting, followed by 39% in industry.

Researchers with master's degrees or doctorates account for slightly more than half of the respondents who work solely for themselves.

Disciplines that attract company ownership include geology, industrial engineering, mathematics, and aerospace engineering. Less popular areas for self-ownership include chemistry, chemical engineering, and biology.

A third of self-employed researchers make $70,000 or more, 23% make between $50,000 and $69,999, 27% between $30,000 and $49,999, and 17% make $29,999 or less.

"Corporate America does not know how to utilize research and technology for profit in large organizations," says William Farone, owner of Applied Power Concepts, Tustin, CA. "Small companies appear to be the only current solution."

Working for yourself, however, is not always a bed of roses. While you gain independence, you often give up support services and work long hours alone solving problems.

Mi Aronson, an independent consultant based in Orlando, FL, lists low pay and poor benefits, inadequate facilities, and insufficient staff as the least satisfying aspects of his job.

Independent consultants suffer from a lack of stimulating interaction with colleagues, says R.J. Reilly, St. Paul, MN. "There's a danger of drinking your own bath water."

Four percent of respondents enjoy the best of both worlds—working for themselves and working for other employers. This group, too, is overwhelmingly male (97%).

More than half (52%) work primarily in industry, 17% in consulting, 15% in government, 11% at universities, and 5% in other categories.

Computers, industrial engineering, and geology are popular areas to combine jobs and company ownership, while chemistry and chemical engineering are the least popular.

Approximately 41% who combine self employment with other jobs make between $50,000 and $69,999; 38% make between $30,000 and $49,999; 15% make more than $70,000; and 6% make less than $29,999.

What do these results say about the entrepreneurial spirit of U.S. researchers—and what do they mean to high-technology companies?

For one thing, employers should not take the concerns of these budding entrepreneurs lightly. With loyalty to "the organization" on the wane and the supply of technical personnel diminishing, you could come up short of good people.

Most important, be aware that one out of three of the researchers in your laboratory is a budding entrepreneur. Keep them happy, or tomorrow they could be your latest competition. **R&D**

Please fill out the second annual R&D Magazine *Career Satisfaction Survey, located elsewhere in this issue.*

READER RESPONSE PANEL

Please rate your interest in this article by circling the appropriate number on the Reader Service Card.

High **501** Medium **502** Low **503**

R&D SOFTWARE

Laboratory Stirrers

LabMaster II custom software controls the company's LabMaster II Model 2500 Series stirrers for precise performance and data acquisition. Changes made at the keyboard are downloaded immediately to the stirrers.
LIGHTNIN **Circle 271**

Data Analysis and Display

S-PLUS is an interactive computing environment that includes a full-featured graphical data analysis system and an advanced quantitative programming language. The program displays data and provides high-quality output for presentation and publication.
Statistical Sciences Inc. **Circle 272**

Full-Screen 'Paint' Program

The ColoRIX VGA Paint 1.3 program offers advanced full-screen and pixel-by-pixel editing. Files can be imported from or exported to all major desktop publishing, CAD, and presentation graphics programs.
RIX SoftWorks Inc. **Circle 274**

Workstation Image Analysis

Real Color Discrimination software enhances and segments images based on color for the company's VIDAS and IBAS workstations. It also measures color using an HLS (hue, luminance, saturation) color modeling scheme.
Carl Zeiss Inc. **Circle 275**

Mac Chemistry Graphics

ChemIntosh II is a drawing program designed to create publication-quality graphics for chemical reports and papers. The updated program adds 45 new features to the original version.
SoftShell International Ltd.
Circle 270

Object Translation Code

An object translation code (OTC) is available now to bridge the gaps between DOS and UNIX and permit users to preserve their existing investment in programs and programming knowledge. The OTC runs as a stand-alone on the UNIX system.
TransWare Enterprises **Circle 276**

Circuit Troubleshooting

Version 6.0 of the Huntron Tracker 5100 DS electronics troubleshooting tool comes with 12 new features that enhance the user's ability to find circuit board problems. The new version also incorporates 19 significant program modifications.
Huntron Instruments Inc. **Circle 277**

High Tech Basic Upgraded

Complex numbers, loadable device drivers, high-resolution display support, international character support, and syntax extensions have been added to High Tech Basic release 3.0 for data transfer between HP workstations and DOS-based systems.
TransEra Corp. **Circle 278**

Security for PC/LANs

With Triumph! 2.0 installed on your networked PC, you can lock out unauthorized users, keep your data private, and analyze PC and software usage. The new release provides both increased security and faster log-on to the network.
Micronyx Inc. **Circle 279**

Chemistry Made Easier

Management of chemical reaction information has become easier with the release of REACCS version 8.0. This program assists in the compounding of chemical products, using proprietary databases to identify possible target molecules.
Molecular Design Ltd. **Circle 280**

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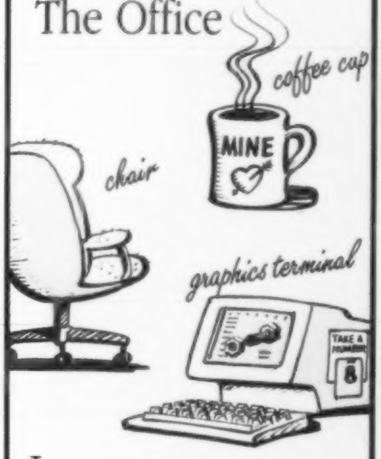
Three Things You Shouldn't Have To Share At The Office



In the workplace you would never think of sharing your mug or chair. So why are you running down the hall to find out if there is a terminal available for your mainframe graphics applications? With TGRAF software and your desktop computer there's no reason to ever share a terminal; you can now have a powerful graphics terminal on your desk, inexpensively.

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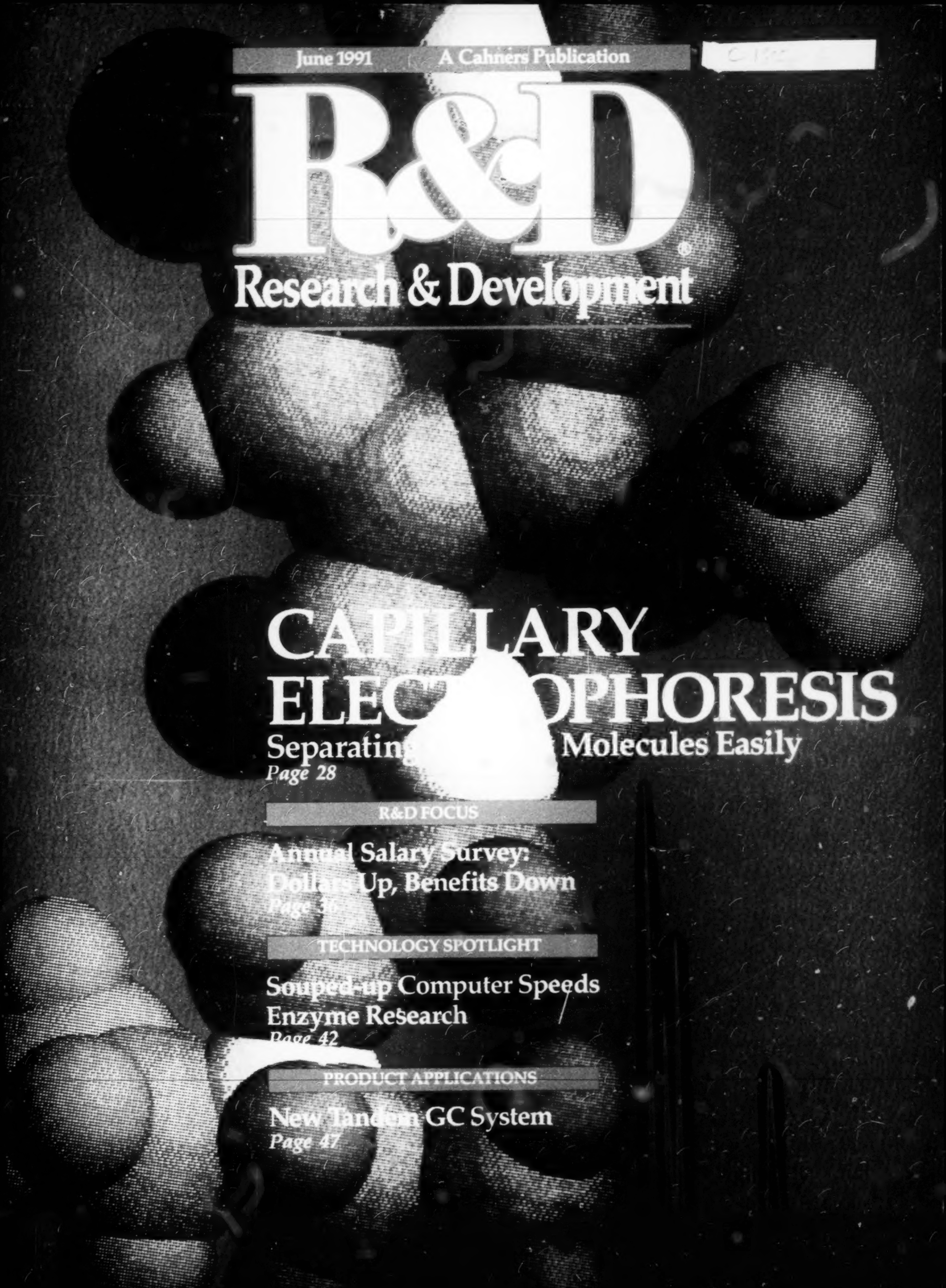

CAPILLARY ELEC[illegible]OPHORESIS

Separating [illegible] Molecules Easily

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New Tandem GC System

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The International Magazine of Research and Development

R&D FOCUS

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CE is an up-and-coming separations technique that offers you more potential applications than either HPLC or HPGC.

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New Tandem System Expands GC Peak Resolution 47
Multidimensional gas chromatography can give you full separations of complex organic mixtures.

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ABOUT THE COVER Capillary electrophoresis separates complex molecules quickly. The metoclopramide image was optimized on the CAChe Worksystem by Steve Wright, Tektronix. The electropherogram courtesy of Herbert Schwartz, Beckman Instruments. For more on CE, turn to page 28.

R&D BUSINESS

New ICs Push U.S. and Japanese Growth In Electrical Measuring Instruments

Japanese and U.S. analysts are forecasting 7% or more annual growth in the sales of electrical testing instruments through 1994, following increased demand for testing equipment related to 4-, 16-, and 64-Mbit DRAM chips in both countries.

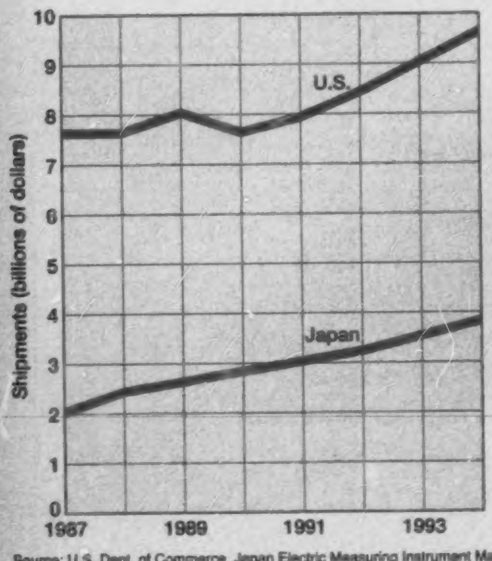
Increased satellite broadcasting and mobile communications, and new communication networks such as ISDN, are helping drive the increased growth forecasts by the U.S. Dept. of Commerce, Washington, DC, and the Japan Electric Measuring Instruments Manufacturers' Assn., Tokyo.

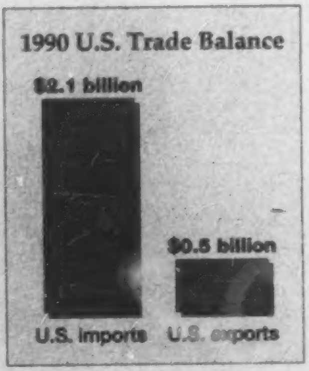
Electrical test instruments mentioned include signal generators, communication test equipment, oscilloscopes, spectrum analyzers, automatic test equipment, and panel instruments.

U.S. shipments dropped in 1990 from 1989 levels, a result of soft defense demand and relatively few new semiconductor devices from domestic manufacturers. Japanese shipments increased in 1990 reflecting an earlier transition by Japanese manufacturers from 1-Mbit DRAM production to higher density products.

U.S. instrument exports exceed imports by more than four to one, but part of this apparent trade imbalance is negated by the growth of Japanese investment in U.S. manufacturers. Nine U.S. electrical test equipment facilities are owned by Japanese firms. These account for almost 10% of the total U.S. production employment in this industry. *—Tim Studt*

U.S. and Japan See Strong Growth In Electric Test Equipment

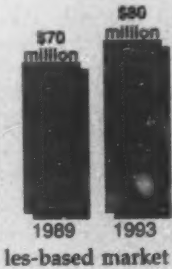



1990 U.S. Trade Balance

Shipments of electric measuring instruments are forecast to increase 7% annually from 1991 through 1994 for U.S. suppliers and 7.9% for Japanese firms.

Source: U.S. Dept. of Commerce, Japan Electric Measuring Instrument Manufacturers Assn.

Slow Growth for X-ray Diffraction Systems



The market for x-ray diffractometers is forecast to grow 3.4% annually over the next four years to $80 million in 1993, according to Strategic Directions Intl., a Los Angeles-based market research firm.

The leading purchasers of these instruments are universities and government, with the main users being chemical and petroleum firms.

Co-Venturing Creates New Foreign Markets

Product-oriented U.S. firms have the opportunity to design and build production facilities for foreign entrepreneurs, according to Jack Baranson, a senior associate at the Illinois Institute of Technology Research Institute, Chicago.

"The Chinese government, for example, has recently set up a joint venture with a U.S. firm to design and build a series of plants for Chinese enterprise groups in China," says Baranson. "Co-venturing is likely to be the predominant option in newly industrialized countries."

Some product manufacturers have already begun restructuring to include process development. For instance, UOP Inc., Des Plaines, IL, now has three distinct profit centers—a product manufacturing group, a design engineering group that develops new products and processes, and a construction engineering group that designs and builds industrial plants. ☐

Federal R&D Grows, But All Is Not Rosy

U.S. research capabilities have grown substantially over the past 30 years, but the Federal research system must seek improvements in the 1990s, according to a recent report issued by the U.S. Office of Technology Assessment.

The report, *Federally Funded Research: Decisions for a Decade,* states that Federal research policy makers must establish new methods of setting priorities; devise ways to cope with and understand research expenditures; develop human resources for research throughout the educational system from elementary through graduate school; and obtain comparable data from all agencies to main-

Salaries Up, Benefits Down, U.S. Researchers Say

Nearly nine of every 10 employees surveyed got raises last year, but many also saw cutbacks in their total compensation packages.

By *John Morkes, Associate Editor,* R&D Magazine

***Winners in 1990** included mathematicians, 8.3% of whom got raises of at least 14%, and aeronautical engineers, who had the highest median salary, $58,333. Not faring so well were geologists, 21% of whom received no raise at all.*

There is good news and bad news to report about the compensation packages U.S. researchers received last year.

The good news is that despite rising health insurance costs and a looming recession, 88.8% of the employees earned salary increases.

The bad news is that many of the raises were small, and take-home pay often was eroded by higher employee contributions for benefits.

That is the general assessment of more than 4,800 respondents to *R&D Magazine's* annual salary survey.

For the 12 disciplines surveyed, 37.6% of the employees received raises of 6% or more (see chart). Chemical engineers, with 41.1%, had the highest percentage of raises of at least 6%, and geologists, with 25.6%, had the lowest.

For each discipline, the most common raise amount was between 2% and 5%.

Aeronautical engineers had the highest median salary in 1990, $58,333, followed by physicists, with $58,062. Industrial engineers ranked last, with $46,636, a drop of 6.1% from last year's survey.

In 1990, 43.9% of the respondents received raises that beat inflation, down from 46.5% the previous year.

Many of those surveyed complained that their raises were too low.

R&D Salary Survey: How Do You Measure Up?

All Disciplines Compared	1990 Salary Raise Amount						1991 Salary Range			Years With Present Employer		
	None (%)	Less than 2%(%)	2 thru 5% (%)	6 thru 9% (%)	10 thru 13% (%)	14% or more (%)	Median	$20,000 (%)	>$100,000 (%)	Median	<1 (%)	>36 (%)
Aeronautical Engineer	7.5	—	62.5	21.3	6.3	2.5	$58,333	—	—	12.4	—	2.5
Biology/Biotechnology	11.3	1.4	48.4	26.5	7.2	4.6	49,838	2.0	2.6	8.6	5.5	1.4
Chemical Engineer	12.0	0.6	45.8	29.5	8.4	3.2	54,750	—	4.5	8.9	6.5	2.3
Chemist	8.7	0.7	49.8	29.1	7.6	3.4	51,794	0.8	1.8	10.6	3.2	1.7
Electrical Engineer	11.5	1.6	53.2	23.5	7.1	2.5	54,030	1.4	2.1	9.5	2.1	2.1
Geologist	21.0	4.6	48.9	20.9	4.7	—	55.500	—	—	11.2	6.7	—
Industrial Engineer	15.9	1.6	52.4	20.6	5.1	4.5	43,636	—	—	6.5	6.3	—
Materials	11.6	7.8	49.9	29.1	5.7	1.8	54,107	1.3	2.3	8.1	4.4	1.3
Mathematician	16.7	4.4	41.7	25.0	4.0	8.3	56,666	—	4.2	13.0	4.3	4.1
Mechanical Engineer	13.2	0.7	48.5	27.0	8.3	2.4	49,578	0.3	2.0	7.9	5.2	1.5
Nuclear Engineer	11.9	—	59.5	26.2	2.4	—	55,010	—	4.8	11.9	2.6	2.2
Physicist	14.1	0.9	47.4	25.8	7.5	3.3	58,062	0.6	4.5	8.6	4.2	0.9

Discipline Rankings by Median Salaries

Rank 1991	Rank 1990	Discipline	Median Salary 1991	Median Salary 1990	Percent change
1	1	Aeronautical Engineer	$58,333	$56,111	3.7
2	2	Physicist	58,062	54,500	6.5
3	8	Mathematician	56,666	49,998	13.3
4	6	Geologist	55,500	51,250	8.3
5	*	Nuclear Engineer	55,010		
6	4	Chemical Engineer	54,750	52,931	3.4
7	*	Materials	54,107		
8	7	Electrical Engineer	54,030	50,978	5.9
9	10	Chemist	51,794	48,312	7.2
10	12	Biology/Biotech	49,838	46,315	7.6
11	9	Mechanical Engineer	49,578	49,280	0.6
12	11	Industrial Engineer	43,636	46,448	−6.1

*New categories this year

The salary race: *Aeronautical engineers and physicists again led the pack, as industrial and mechanical engineers fell back. Mathematicians enjoyed the biggest gain.*

"Merit review rates me highly, but raises never match the inflation rate," said an industrial materials researcher.

"I get 4% of $50,000 for a raise, and the CEO gets 21% of $5 million!" exclaimed a chemical engineer.

University researchers complained that they would make more money working in industry.

"Academic salaries stink," a chemist said. "I'd probably double my salary if I were in an industrial lab."

A small salary or raise would be frustrating enough, without the burden of higher employee contributions for what respondents said were declining health benefits.

"The employee's share of costs increases each year to wipe out any salary increases," said a government biologist.

"We continue to pay more and more money for less and less coverage on our medical insurance," said an industrial physicist. "It's like a double increase, to pay more for less coverage every year."

Employers are switching to less expensive insurance policies, largely because hospitalization policy costs jumped 30% in the span of a year, said Sanford Rose, president of Sanford Rose Associates International, Akron, OH, a recruitment firm for high-tech fields.

As a result, more health insurance costs were passed on to employees, which angered many respondents.

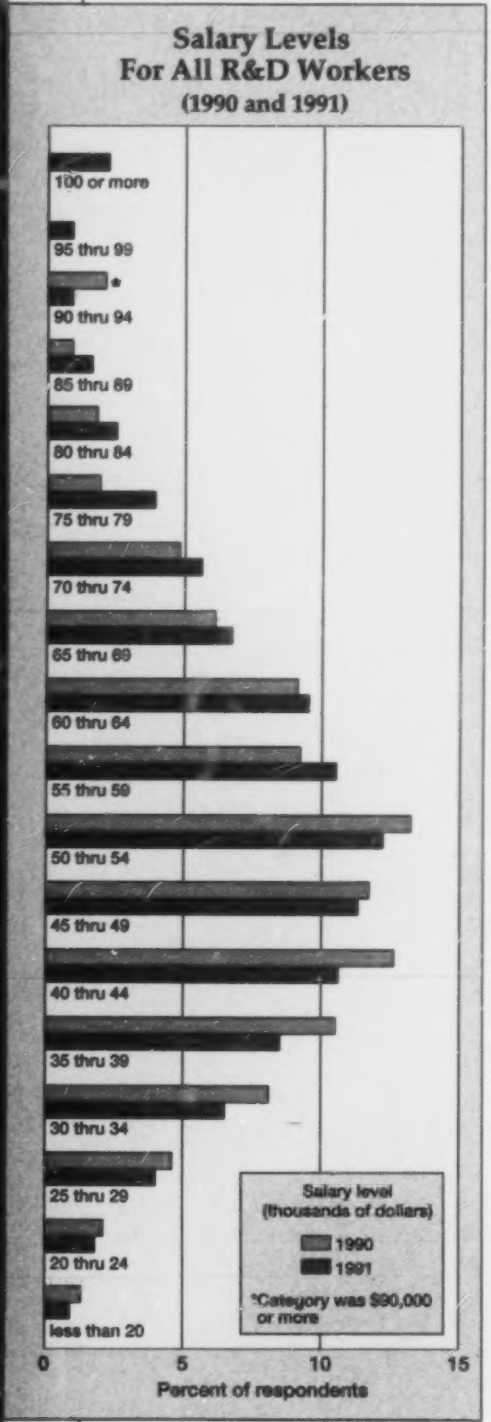
"The company has cut the medical plan to cut its costs," said a chemist. "It has resulted in less coverage and more paperwork. We need a national health insurance plan available to all, financed by employer taxes. Health costs and availability are a disgrace."

The subject of financial benefits also generated angry comments. Across all disciplines, less than half of all respondents were offered profit sharing, merit bonuses, or patent awards/royalties by their employers (see "Financial Benefits" chart). Nevertheless, a majority of employees in 10 disciplines were offered 401(k) savings plans.

Employees said they want more fi-

Age, Years			Experience, Years			Highest Academic Degree				Financial Benefits			
Median	<26 (%)	>65 (%)	Median	<1 (%)	>40 (%)	<BS (%)	BS (%)	MS (%)	PhD (%)	Profit-Sharing	401(k) Plan	Merit Bonuses	Patent Awards/ Royalties
45.1	3.8	5.1	21.5	—	6.3	6.3	31.4	41.3	21.2	23.8	60.0	28.8	49.0
43.9	1.7	3.4	16.1	—	1.7	2.0	19.5	24.7	53.7	17.2	42.4	29.9	20.9
40.1	2.9	1.9	13.5	1.0	1.6	3.2	39.5	29.4	27.8	29.9	68.1	33.9	31.6
43.8	1.9	2.3	17.4	0.6	1.7	3.6	33.8	20.3	42.3	28.7	64.5	30.4	23.5
44.3	2.3	1.4	16.9	0.5	1.1	16.8	35.6	30.8	16.8	28.1	66.8	29.9	33.9
45.4	—	4.4	21.2	—	6.8	4.4	15.6	33.3	46.7	22.2	48.9	37.8	15.6
38.7	1.6	—	9.3	3.1	—	21.9	39.1	28.1	10.9	36.5	52.4	31.7	28.6
41.9	2.9	2.1	15.6	0.3	1.8	7.5	26.4	28.1	40.0	20.6	64.8	28.9	46.4
43.7	4.2	—	13.3	—	—	—	41.7	37.5	20.8	29.2	54.2	41.7	25.0
43.4	2.5	2.3	13.8	1.6	1.4	16.9	39.9	29.3	13.7	27.3	63.0	27.2	33.8
45.9	—	2.3	18.2	2.5	—	7.1	23.8	28.6	40.5	17.9	71.8	35.7	36.1
45.4	3.0	1.5	18.2	—	0.9	2.1	18.7	26.2	53.0	21.9	53.5	31.0	42.2

'I am tired of being in the front lines of the battle to balance the Federal budget,' says a government physicist.



Salaries for R&D workers in 1991 are generally about the same or slightly higher than salaries in 1990, according to more than 4,800 survey respondents.

nancial benefits and want them linked more closely to their accomplishments.

"There's no real incentive for good work. Don't work for the government!" exclaimed an agricultural engineer.

"We used to be able to get a bonus based on performance," said an industrial chemist. "Now, it's based solely on level, and you have to be two levels higher than I am to get it—then it's automatic! Why work hard, just so the next guy can get a fat bonus check?"

Overall, respondents said they were generally dissatisfied with their benefits packages, which they see as diminishing.

"My compensation package is lousy and rapidly getting worse," said one electrical engineer.

"The trend has been toward decreasing benefits," said a physicist at a leading computer manufacturer. "World-class companies should have benefits that are 'world class.' Ours are more like 'Third-World class.' "

"We had the best profit-sharing plan when we had no profits," said a chemist. "The plan was drastically revised when we began to see meaningful profits."

Many government employees who complained about low compensation also expressed concern about possible furloughs. The surveys were mailed at the time of the government budget crunch last October.

"With the limited prospects for the future, including the likelihood of government furlough in the immediate future, it is hard to keep my spirits up and my wife happy," said a chemist.

"I am tired of being in the front lines of the battle to balance the Federal budget," said a government physicist.

Respondents identified a trend in employee compensation toward "cafeteria-style" benefits packages that let employees choose their own benefits, up to a set dollar amount.

One industrial physicist said he likes the "freedom to choose from a 'cafeteria list' of benefits."

The average employee may actually lose benefits as a result of the cafeteria-style plan, according to recruiter Rose, because it is often a cost-cutting measure taken by the employer. However, the survey shows that some employees prefer it. Those without dependents are interested, for example, because the plan offers them benefits they want instead of insurance coverage they do not need.

Increases in Rate of Pay for All R&D Workers*

Percent of respondents

Amount of Increase	1991	1990	1989
None	11.2	9.2	9.3
Less than 2%	0.9	2.1	5.3
2 thru 5%	50.3	54.9	54.8
6 thru 9%	27.2	24.7	22.2
10 thru 13%	7.2	5.9	5.6
14% or more	3.2	3.2	2.7
Ahead of inflation	43.9	46.5	44.2

*Granted in preceding year for year shown

Despite the looming recession, many of the percentage increases in 1990 were higher than in previous years.

Not all respondents had only negative comments, however. Some said they like at least part, if not all, of their compensation packages.

"Working in a university cost me about $25,000 a year, but it was worth it to do my own research," said a chemist.

"Merit bonuses in our division have resulted in increased productivity," a materials researcher said.

"There is an on-site fitness center, which is excellent," said an industrial chemist.

"The 401(k) savings plan helps avoid taxes and save for retirement," said another industrial chemist.

For the most part, though, respondents had few positive things to say. When asked "What do you like best about your compensation package?" one mechanical engineer simply wrote, "Nuttin." **R&D**

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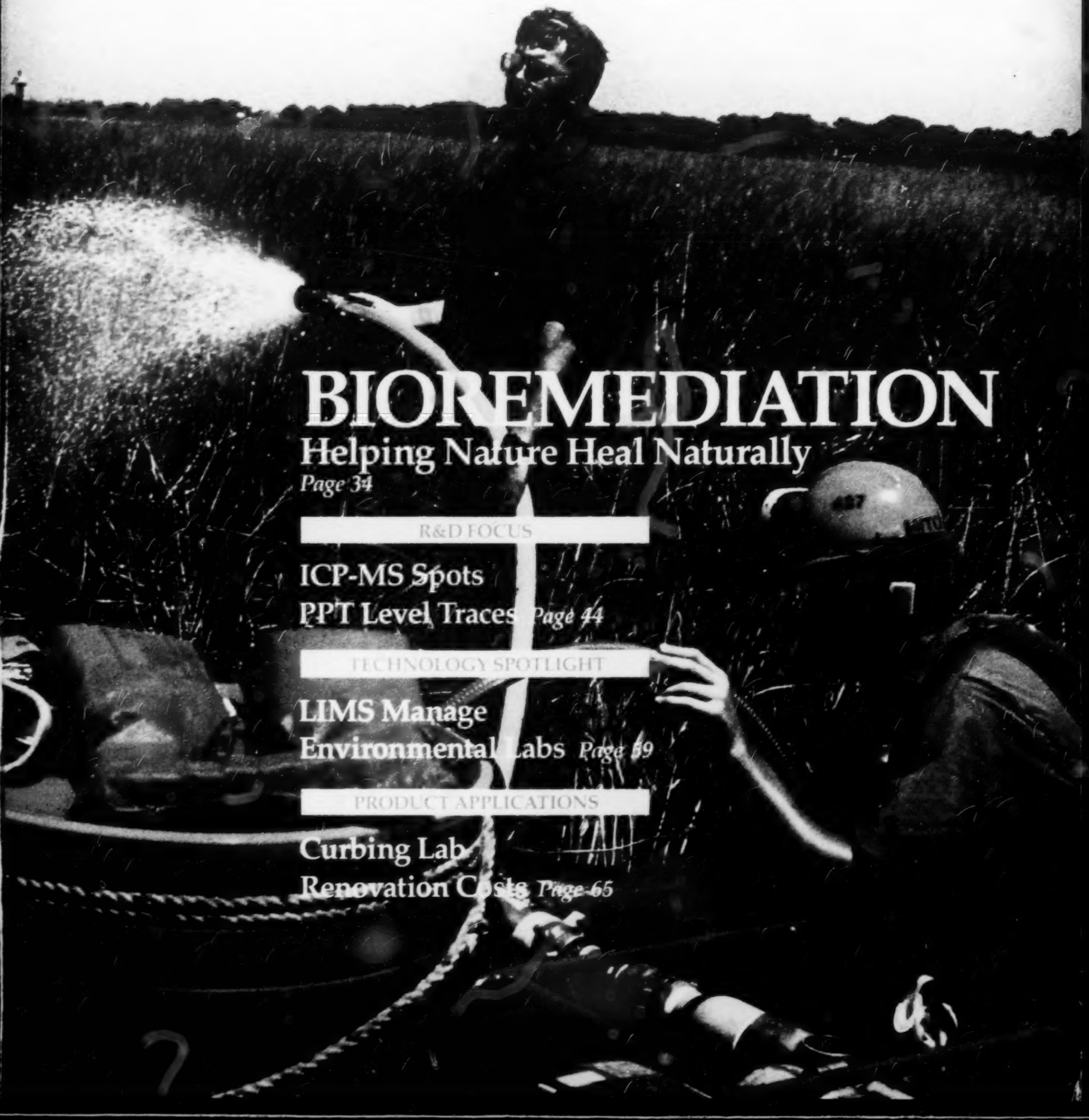

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ABOUT THE COVER Hydrated bacteria are sprayed onto an oil spill to start the process of bioremediation. See article, page 34. *Photo: Gavin R. Villareal/Texas General Land Office.*

R&D BUSINESS

Survey Reveals R&D Purchasing Patterns

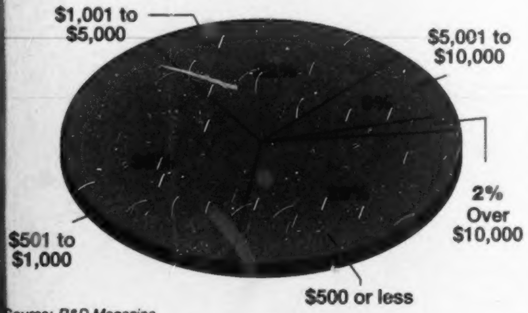
Processes for approving the purchase of capital equipment for R&D laboratories follow very definite patterns, according to a recent survey performed by *R&D Magazine* at the 1991 Pittsburgh Conference on Applied Spectroscopy and Chromatography.

Laboratory capital equipment is generally purchased either as part of a budgeted process, for specific projects, or to replace existing equipment, says Tom Kane, a market researcher for Cahners Publishing, Des Plaines, IL, who organized the survey.

Budgeted purchases, which make up about 75% to 100% of the total capital budget, take the longest time to approve, about three to 12 months. Most of these purchases involve relatively high dollar amounts, generally over $25,000. They also require a formal justification procedure that includes cost, payback, and return on investment. The approval process goes through many levels of management and may require authorization by the chief operating officer of the organization.

Project purchases usually come from a budgeted "slush" fund and can comprise 5% to 25% of the capital budget. Approval for these purchases is faster and less complicated than for budgeted equipment purchases. They generally are purchased by the R&D department, take three to six months to complete, and usually cost less than $10,000.

Replacement purchases for laboratory capital equipment, by their very nature, require the fastest approval and purchasing process, generally taking less than three months. ☐



How Much Can You Buy Without Your Boss's Approval?

Percent of Respondents by Dollar Limit

Source: *R&D Magazine*

Number of People Involved in Approval	
Organization size	**Persons needed for approval**
<1,000	3 to 4 (<$7,000)
	5 to 6 ($7,000+)
1,000 +	3 to 4 (<$22,200)
	7 to 8 ($22,200+)

Two-thirds of the researchers polled in an R&D Magazine *survey said they could purchase up to $1,000 without having to get their boss's approval.*

EPA Gives Money for Green Ideas

Small firms are receiving up to $25,000 to develop pollution-prevention approaches as part of the U.S. Environmental Protection Agency's Environmental Risk Reduction Program.

Under a 2% small business set-aside known as Pollution Prevention by and for Small Businesses, small companies are selected to demonstrate their technologies and transfer the information to potential users. This year, 17 of 176 proposals were chosen: seven are recycling techniques and 10 involve source reduction. Research briefs will be distributed to encourage the transfer of successful methods.

A second solicitation for proposals will be announced this summer; applications will be due October 15. Between 13 and 17 proposals will be selected in January 1992 to begin another 12-month project schedule.

For more information: Call Kenneth Stone, Risk Reduction Engineering Research Laboratory, EPA, 513/569-7474. —*Cheryl Pellerin*

Strong Growth Seen For ICP-MS

Environmental demands are forecast to fuel 10.8% annual growth in inductively coupled plasma mass spectrometers (ICP-MS) bringing sales to $50 million in 1995, according to Strategic Directions Intl., a Los Angeles-based management consulting firm.

ICP-MS instruments are used to detect trace elements in very low sample concentrations. About 40% of the market for these instruments involves environmental testing.

Economic Upturn Sure, But Weak

A textbook example of an economic upturn is unfolding, according to Kermit Baker, an economist at Cahners Economics, Newton, MA. Recent indicators such as falling interest rates, increasing stock market prices, a turnaround in home building starts, and an increase in the consumer confidence index all are classic indicators of an economic expansion.

However, the upturn will be relatively weak, says Baker. Lower consumer spending, a currently stalled consumer confidence level, and a still declining industrial production index are slowing growth.

Because of the U.S. Federal Reserve Bank's cut in the prime discount rate to 5.5%, interest rates are about the lowest they will get in this business cycle. Further interest rate reductions are not likely, due to concerns that they might increase inflation. An improving domestic credit condition and weakening foreign economies, which are slowing foreign borrowing, also limit further rate reductions.

The early signs of an upturn lead Cahners economists to forecast a slight increase of 0.1% in the gross national product for 1991 and a 3.1% increase for 1992. **R&D**

R&D NEWS

DARPA's Reorganization Raises Eyebrows

The Defense Advanced Research Projects Agency (DARPA), the Pentagon's pre-eminent R&D agency, has reorganized to sharpen its focus on technological development. But this may actually make the agency less effective, some observers fear, particularly since the reshuffling follows the ouster of Craig Fields, DARPA's former director.

DARPA provides hundreds of millions of dollars to high-risk, high-payoff technological projects and demonstrated "revolutionary approaches" that may lead to improved weapons systems (see *R&D*, November 1989). "New technical ideas are a DARPA hallmark," is the way Victor Reis, DARPA's present director, summarizes the agency's commitment.

DARPA's restructuring, announced in May, consolidates similar activities that had existed in various offices and creates 10 new offices for programs that have "well-defined customers and products," the agency said.

The new offices include: Advanced Systems Technology, for strategic and tactical military systems; Computing Systems Technology, to work on scalable parallel and distributed heterogeneous computing systems; Defense Science, to identify and develop the most critical emerging technologies in materials, chemistry, electromagnets, and other fields; and Software and Intelligent Systems Technology, to work on machine intelligence and software engineering.

DARPA's Victor Reis

Craig Fields left his post as director in April 1990 after running afoul of Pentagon and White House officials. Fields had been steering DARPA to fund dual-use technology programs—such as high-definition TV systems and advanced semiconductors—that could have commercial as well as military benefits. Congressional observers and others said senior Bush Administration officials had opposed this as the creation of a de facto "industrial policy."

A bipartisan coalition of 11 congressmen blasted Fields's ouster as "a major breach of our future economic security." But Pentagon officials denied that Fields had been fired, only reassigned. Today, Fields is president and CEO of the Austin, TX-based Microelectronics and Computer Technology Corp., a consortium of 21 high-tech firms. Fields could not be reached for comment and previously has declined to discuss what happened.

Raymond Colladay, a former DARPA director who now is a vice president in Martin Marietta's Littleton, CO, office, told *R&D* that Fields "took too high a profile" as far as some people were concerned.

Fields attracted top engineers and technical managers to DARPA and persuaded them to take pay cuts in exchange for the excitement and satisfaction of running leading-edge programs in a relatively hassle-free bureaucratic environment.

"Key to DARPA is the empowerment of these young engineers and scientists," a congressional expert who requested anonymity observed of the reorganization. "You have to get out of their way and let them do their jobs.

"I tend to be nonchalant about how the nameplates change," he added, "but I am worried because those people (who fostered such freedom in DARPA) are out." Fields, he said, "was not one of the boys. He tended to go around people" to get things done.

Current DARPA director Reis declined to talk with *R&D* about changes at the agency. But Jan Walker, a spokeswoman for the agency, said the reorganization would not be noticed by industry.

"The same program managers will manage, and the companies will call the same people as in the past," Walker said. "Internally, folks are simply arranged into different offices."

The reorganization, she added, is intended "to take better advantage of technology and to allow cross-fertilization of technologies with like technologies."

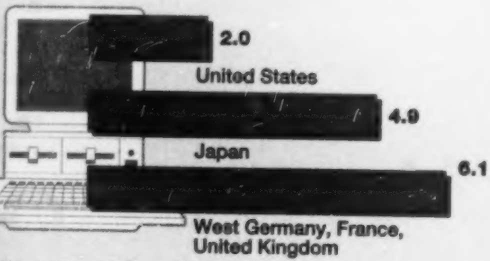
During the last three decades, DARPA-funded projects have led to the development and commercialization of computer time-sharing, advanced aeronautics, new types of composite materials, telecommunications packet-switching, and software for high-speed computing architectures.

At present, the agency is funding innovative programs such as optoelectronics and high-definition displays, high T_c quantum devices, new microelectronics manufacturing technologies, and the exploration of synthetic environments.

DARPA has asked Congress for $1.2 billion in 1992. —*Ted Agres*

U.S. Lags in Budget Share Spent On Computer R&D

(Percent of government R&D budget)



Source: Computer Systems Policy Project

In 1989, the U.S. ranked behind major European competitors and Japan in the portion of the government's R&D budget spent on computer-related R&D. West Germany, France, and the United Kingdom spent an average of 6.1%.

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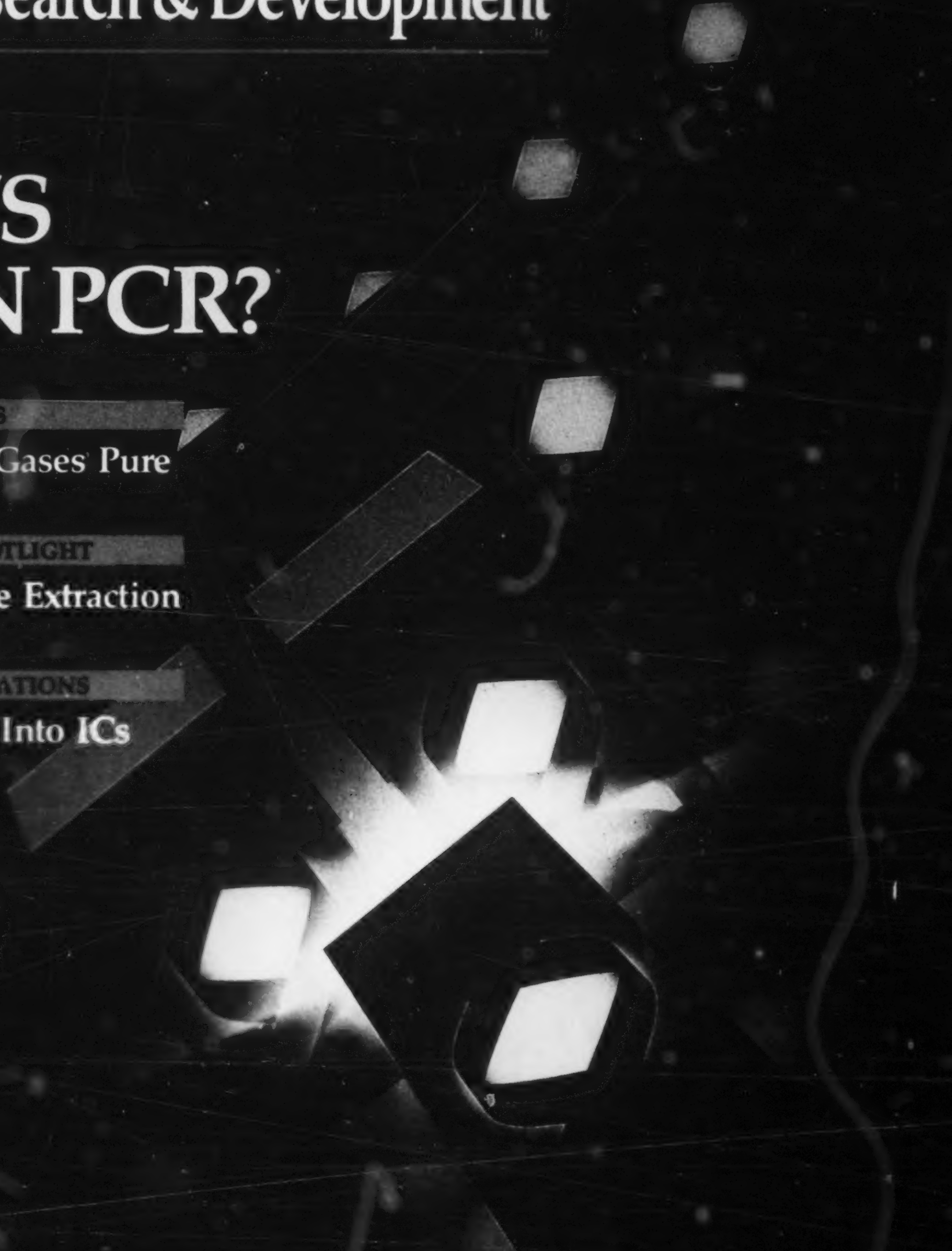

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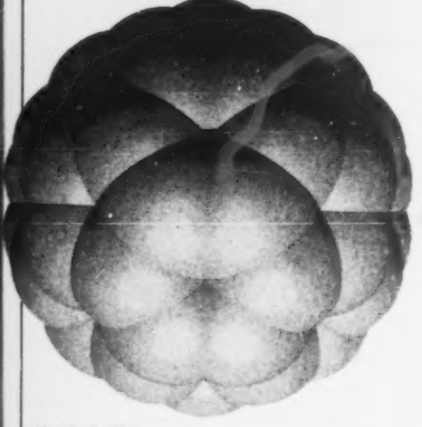

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ABOUT THE COVER Researchers are finding new uses for PCR nearly every day. For more on this, see article on page 30. *Photo: Perkin-Elmer Cetus Instruments, Norwalk, CT.*

R&D FOCUS

Uses for PCR Are Multiplying In Gene-Related Research 30

The polymerase chain reaction is proving to be a powerful tool for all researchers who need to amplify sections of DNA.

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Most researchers using specialty gases say purity is their biggest concern, but meeting current demands isn't that easy.

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Here are some basic solid phase extraction techniques to help you solve those challenging sample preparation problems.

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BEEM Takes STM Imaging Below the Surface 63

Ballistic electron emission microscopy lets you peer into the electronic structure of semiconductor devices.

R&D BUSINESS

U.S. Technology Open to Foreign Investors

Foreign investors who bought into U.S. high-tech industries in the past several years have had little or no opposition, despite creation of a special Congressional Committee on Foreign Investment in the U.S. (CFIUS), says Linda Spencer, a consultant for the Washington, DC-based Economic Strategy Institute.

CFIUS was created in response to the Exon-Florio amendment to the Defense Production Act, passed in August 1988, which empowered the president to block an investment that might harm U.S. national security.

Only one of the 540 investments reported to CFIUS in the past two and a half years received a negative recommendation from the committee. Only 12 cases were formally investigated. The one negative recommendation involved blocking the acquisition of a U.S. aerospace manufacturer by a Chinese company immediately after the Tiananmen Square uprising.

In some investments, foreign firms bought technology vital to U.S. defense interests. In 1990, for example, Japan's Komatsu Electronic Metals Co. acquired Union Carbide Chemical & Plastic Co., the last remaining U.S. supplier of polysilicon. CFIUS chose not to investigate this purchase.

In three of the CFIUS investigated cases, the investments were restructured to ensure that strategic technology was not transferred out of the U.S.

According to a U.S. Government Accounting Office study, CFIUS initially narrowed its scope by limiting its investigations to only those that have direct military impact. In 1990 CFIUS began investigating only those investments where foreign firms became majority shareholders.

For a copy of *Foreign Investment in the U.S.: Unencumbered Access,* 202/728-0993. —*Tim Studt*

U.S. R&D Forecast to Beat Inflation in 1992

The 10 biggest U.S. industrial R&D spenders are forecast to increase their research spending by an average of 7.1% in 1992 over 1991 levels, according to a recent study by Schonfeld & Associates, an Evanston, IL-based management consulting firm.

This compares to only 4% average R&D increases for the 10 biggest Japanese spenders listed on the New York Stock Exchange, which includes NEC, Hitachi, Matsushita, NTT, Toshiba, Sony, and Honda. The top 10 "other foreign" R&D spenders, which includes Philips, Fiat, Imperial Chemical, Northern Telecom, Glaxo, and Smith Kline Beecham are forecast to increase their average research spending by 8.8%.

Many segments of the computer industry will increase their research spending between 6.5% and 15%, according to the study. However, most increases will be in software development where total R&D spending will exceed $2 billion.

R&D Ratios & Budgets ($295) lists spending forecasts for more than 3,000 companies and 300 industries. For a copy: 708/948-8080. □

U.S. Firms Renew R&D Commitments

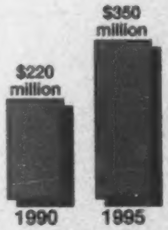
	Top U.S. R&D spenders	1991* (In billions)	1992** (In billions)	Percent change
1	General Motors	$5.76	$6.09	5.6%
2	IBM	5.44	5.79	6.4
3	Ford Motor	3.89	4.22	8.6
4	AT&T	2.41	2.40	-0.4
5	Digital Equipment	1.96	2.16	10.1
6	Hewlett-Packard	1.58	1.74	10.4
7	General Electric	1.58	1.68	6.6
8	DuPont	1.51	1.58	4.6
9	Eastman Kodak	1.46	1.57	7.6
10	Dow Chemical	1.27	1.42	11.5

*Estimated **Forecast

Source: Schonfeld & Associates

General Motors is forecast to be the first company to spend more than $6 billion in R&D. Dow Chemical is the only newcomer to this top 10 list; all others were in 1990's list.

International Sales Drive FTIR Growth



European and Pacific Rim demand for Fourier-transform infrared (FTIR) instruments will drive 9.6% annual growth to $350 million in 1995, according to Strategic Directions Intl., a Los Angeles-based management consulting firm.

This growth reflects FTIR replacement of dispersive-IR techniques due to FTIR's greater analytical capabilities and lower price. FTIR is used in R&D and forensics applications.

FDA Is Biggest Barrier to Biotech Firms' Success

The U.S. Food and Drug Administration was ranked number one of 22 possible barriers to the success of U.S. biotech firms, according to a recent survey by the North Carolina Biotechnology Center, Research Triangle Park.

The survey of 166 U.S. biotech firms included external factors, such as financing sources and government regulations, and internal factors, such as management expertise and the availability of personnel. The factors that received the highest ranking were:

U.S. Food and Drug Administration
U.S. patent decisions
Management expertise
Federal regulations
Availability of technical personnel
Foreign patent decisions
R&D technical expertise
Availability of marketing personnel

The lowest-ranked barriers, or those factors that were not considered to limit the success of a biotech firm, included the availability of materials, the U.S. Dept. of Agriculture, local government regulations, seed funding, government research funds, and bioprocessing expertise. **R&D**

Researchers See Bright Prospects for New STEM

The Cavendish Laboratory, Cambridge Univ., England, has a new approach to scanning transmission electron microscopy (STEM) that could lead to major improvements in our understanding of microstructures.

"The idea is to record diffraction patterns and images simultaneously, so that a computer program can combine the four-dimensional information to give you higher resolution," says L.M. Brown of the lab's Microstructural Physics Research Group.

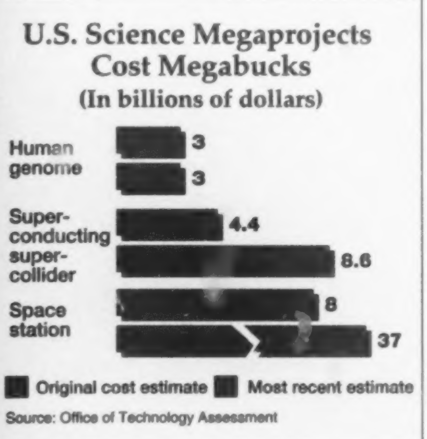
The researchers believe they can improve the spatial resolution of STEM from 0.5 nm to better than 0.1 nm.

U.S. Must Revamp R&D Funding, OTA Says

The government of the United States, facing increased global competition and domestic financial pressures, must re-evaluate its priorities for R&D funding, says the Office of Technology Assessment (OTA), a congressional agency.

In the report "Federally Funded Research: Decisions for a Decade," the OTA offers recommendations for solving problems in Federal funding for scientific research.

U.S. Science Megaprojects Cost Megabucks
(In billions of dollars)



Source: Office of Technology Assessment

Overall costs for certain Federally funded science projects are enormous, says the OTA. Over time, cost estimates can even quadruple for some megaprojects, such as the manned space station.

The report urges Congress to demand that the Bush Administration set priorities within and across agencies for science megaprojects. It says that criteria are unclear for megaprojects such as the superconducting supercollider, the human genome project, and the manned space station (which the OTA says has "little justification on scientific grounds"). The OTA also says there is no way to evaluate the total Federal government research portfolio across agencies in terms of national objectives.

Furthermore, there should be greater cost-accountability, especially regarding allowable indirect costs (overhead), and better estimates of future expenditures, particularly for megaprojects. One reason for this problem is rising research costs, which are outpacing available Federal funds, the OTA says.

Agencies also should refine internal data collection and analysis to improve research decision-making, according to the report.

The OTA concludes that implementing these and other changes can help government officials make the "tough choices, even beyond merit and constricted budgets, in guiding the research system."

For a copy: Stock #052-003-01241-3 ($12); 202/783-3238. *—Ted Agres*

Scientists Best Fish In Making Antifreeze

Winter flounders don't freeze in temperatures as low as 27 F because their bodies produce a natural antifreeze peptide (AFP) that is about 500 times more effective in preventing ice formation than an equivalent concentration of sugar or salt. So why doesn't someone create a synthetic version?

Well, someone has, and the payoff could be new ways to prevent crops from freezing, noncorrosive substitutes for road salt, and coatings to prevent ice formation on aircraft wings in bad weather. Another use may be as a cryoprotective package for enzymes.

Researchers at Virginia Polytechnic Institute, Blacksburg, have synthesized AFPs that mimic the structure of the antifreeze compound the fish produce but are larger and should work at even colder levels, says Thomas Caceci of the school's College of Veterinary Medicine. The group is the first to design and synthesize an AFP.

***Artificial antifreeze peptide** research by Thomas Caceci's group may result in alternatives to road salt and coatings to prevent ice formation on aircraft.*

"Activity seems to depend on molecular size and the number of places the AFP can contact ice," says Caceci, who heads the research team. "We know they can protect at lower than 27 F, but we really don't know yet what the lowest temperature attainable is."

The researchers postulate that the natural AFP suppresses ice forming inside the fish by binding to ice crystal

Breaking Down the Barriers for Ceramic Matrix Composites

Advances in toughening systems for ceramic composites are enhancing use in industrial high-temperature, wear, and corrosive applications.

By ***Tim Studt****, Senior Editor,* R&D Magazine

Ceramics are almost the perfect structural materials. They're light, strong, hard, chemically inert, and resistant to abrasion. They can withstand extremely high temperatures. Their raw materials are abundant. They really only have two weaknesses: they're brittle and hard to work with.

Researchers are working on these weaknesses with surprising success. The solution has been to make ceramic matrix composites (CMCs).

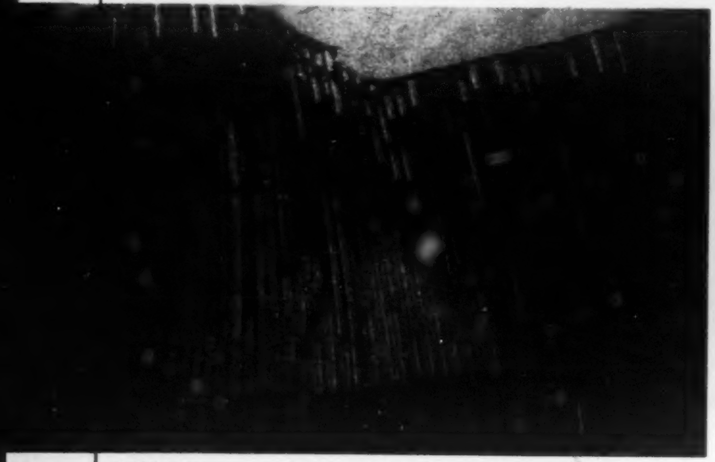
The great potential of CMCs has only begun to be recognized as production scale-up processes prove themselves out and as the first parts find their way into industrial applications—cutting tools, automotive and aerospace engine parts, heat exchanger tubes, and heavy-duty components in process equipment.

Researchers now find that CMC products not only can improve upon and replace existing ceramic parts, but they also can replace metal and even metal matrix composite parts.

Improving the fracture toughness of ceramics started with rudimentary attempts at adding particulates, platelets, and ceramic whiskers. Current technologies include improved versions of these reinforcements and add continuous fibers, matrices created by vapor infiltration and directed metal infiltration, and various types of laminated structures.

"Everyone knows you can improve the performance of a monolithic ceramic by incorporating whiskers into the matrix," says Paul Becher, a researcher in the Metals and Ceramics Division at Oak Ridge (TN) National Laboratory (ORNL). "However, if you have a whisker-like grain structure you can do the same thing, which is taking a little bit of what we learned in the composite area and extending it to monolithic materials."

Whisker-reinforcing technology has improved to the point where it cur-



SEM picture of a fractured *SiC-fiber-reinforced Si_3N_4 reveals poor strength in the through-thickness direction.*

Higher magnification *of the fracture at left reveals a planar matrix fracture and failure of the fiber coating.*

rently is the most economical fabrication method for improving the fracture resistance of a ceramic product. Japanese firms already use whisker-reinforced SiN materials to make automotive turbocharger rotors.

"The whisker raw material cost is still high because you're not making a million parts a year," says Becher. "But you can use fairly standard fabrication technology, such as that used for standard powder processing of monolithic ceramics."

Research in SiC whisker and platelet reinforcements focuses on their high-temperature behavior and production scale-up capabilities. There also is research on reducing the size of platelet reinforcements from 50- to 100-μm across to 10 μm or less across. Large platelets often act more as a flaw than as a reinforcement.

Silicon carbide also is used in most continuous-fiber CMC products. The advantages of SiC are its chemical and thermal inertness to many matrix materials, its oxidation resistance, and its strength at high temperatures.

Continuous SiC fiber-reinforced CMCs have up to five times the fracture toughness of monolithic products. They also have a more gradual failure mode than the catastrophic brittle failure typical of monolithic and whisker-reinforced products.

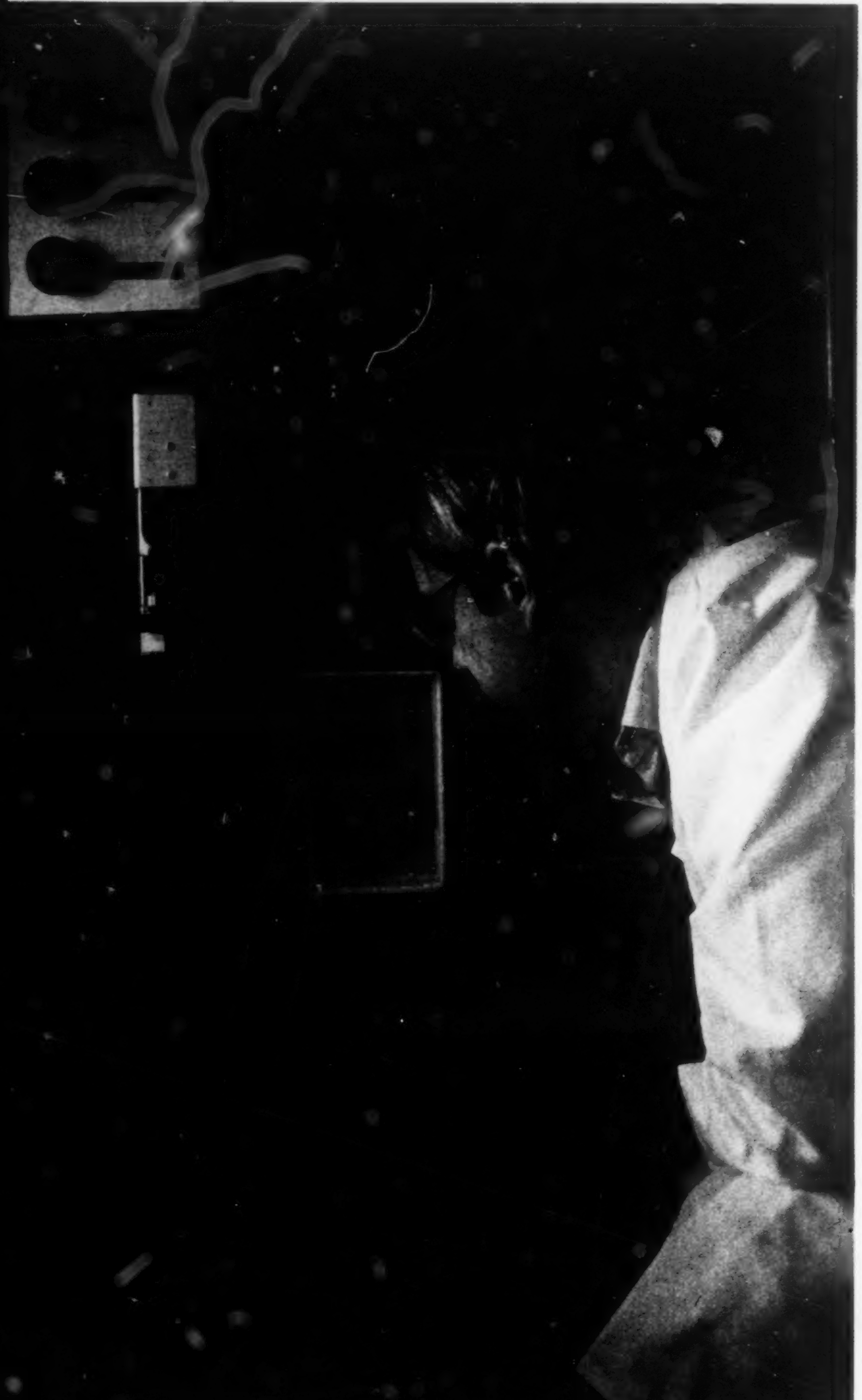
There are two types of SiC fibers available. Small diameter (10 to 15 μm) fibers, such as Nippon Carbon's Nicalon and 3M's Nextel, are relatively inexpensive and can be woven. Large diameter (140 μm) fibers, such as Textron's SCS6, are stiff and hard to work with, but have better strength and high-temperature properties.

Nicalon-type fibers are used more for industrial CMC applications, while SCS6 fibers are used for advanced aerospace applications.

Research in new fibers is directed at further reductions in the oxidation of these SiC fibers. Unless protected or treated, SiC oxidizes steadily when heated to more than 1000 C.

The high temperatures and mechanical stresses that the fibers experience during the fabrication of a continuous fiber-reinforced CMC often limits the overall composite's performance. Researchers are looking for ways to reduce these stresses and temperatures to limit the degradation of the fragile SiC fibers.

"We blended an additive with the



Paul Becher, ceramic researcher *at Oak Ridge (TN) National Laboratory, tests the high-temperature strength of a whisker-reinforced ceramic matrix composite.*

Continuous-fiber-reinforced ceramics have up to five times the fracture toughness of monolithic ceramic materials.

silicon nitride matrix of a hot-pressed SCS6-reinforced part to match the thermal expansion mismatch between matrix and fiber," says Jeff Bright, a research engineer at Ceramatec, Salt Lake City. "With this process, we were able to lower the press temperature 200 C, cut the process pressure by more than half, and still fabricate a composite that can withstand a 300 MPa load at 1400 C."

Narottam Bansal, a materials research engineer at NASA's Lewis Research Center, Cleveland, also works with additives to stabilize a SCS6-reinforced celsian glass CMC. "With this process, we can fabricate a hot-pressed CMC part with an ultimate strength of 500 MPa at room temperature in air."

However, even these fabrication techniques still impart significant stress to the fibers. More research is being performed on the development of lower stress CMC processes.

Chemical vapor infiltration (CVI) is one of the most highly commercialized of these low stress processes. In the CVI process, the CMC matrix is created by reacting two or more vapor species in a heated furnace. The matrix infiltrates and forms on the surfaces of a reinforcing fiber preform.

DuPont is the U.S. licensee of the French Société Européenne de Propulsion (SEP) CVI process. DuPont fabricates both continuous-SiC and continuous-carbon fiber-reinforced SiC CMC products in their CVI process.

Other ceramatists are developing their own CVI processes. Researchers at ORNL have developed a forced-flow process that reduces infiltration time and creates thicker parts.

Researchers at NASA's Lewis Research Center are developing a CVI process that uses low-pressure mixtures of $SiCl_4$ vapor and H_2 gas to deposit silicon throughout a microporous carbon preform, resulting in a thick SiC product.

But DuPont already is making production parts with its process.

"We licensed CVI to solve the problems of scale-up from laboratory-type furnaces to production furnaces," says Warren Hewett, CMC research manager at DuPont, Newark, DE. "We think the design of the furnace is the key to achievement of uniform and reproducible parts."

Most of DuPont's products are for high-speed aircraft, liquid propulsion rockets, and small expendable turbine engines.

"We also are targeting industrial markets, such as those for heat exchangers, where we can provide parts that operate at up to 1100 C for hundreds of hours," says Hewett. "We've already made a 0.6-m × 0.6-m aerospace part and are planning a furnace that can accommodate parts 1.5-m-dia × 2-m high."

Even in CVI, the reinforcing fiber limits how long the CMC survives at an elevated temperature.

"To improve our current SiC/SiC and C/SiC systems, we need to see improved SiC and carbon fibers," says Hewett. Both Nippon Carbon (Nicalon SiC fiber) and Ube (Tyranno Si/Ti/C/O fiber) are developing new fibers with reduced oxygen contents for better high-temperature capabilities.

DuPont also is involved

Forecast for U.S. Ceramics Markets

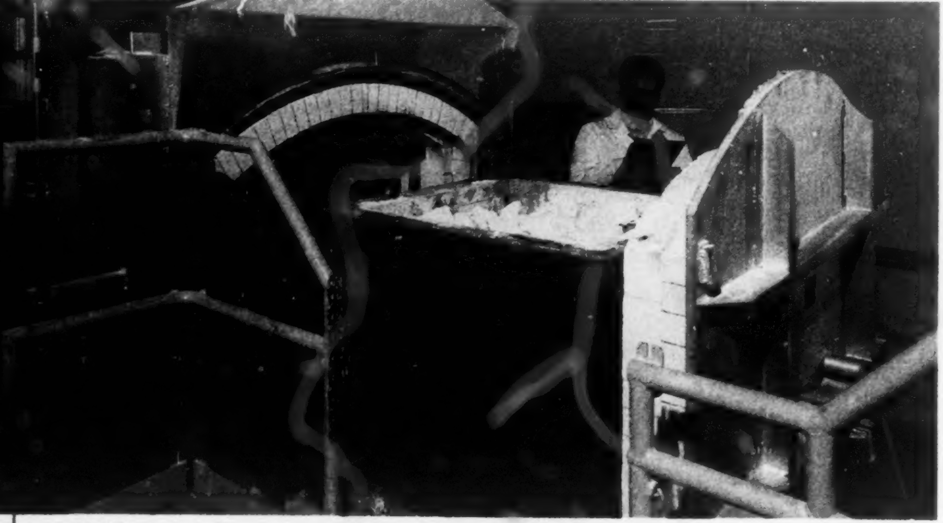
(Millions of current dollars)

	1990	1995	2000
Electronics applications	3,740	6,565	11,360
Structural applications			
Aerospace and defense-related	80 (28)*	200	445
Automotive	81	310	820
Bioceramics	15	34	60
Cutting tools	92 (19)*	246	500
Heat exchangers	15	50	100
Wear parts and other industrial	150 (32)*	320	720
Subtotal (structural)	433 (79)*	1,160	2,645
Grand total	4,173	7,725	14,005

* Est. CMC portion

Source: U.S. Bureau of Mines

***Experts predict that improvements** in the high-temperature performance of CMCs will increase their current $79 million or 18% share of the structural ceramic market.*



***A technician at Carborundum,** Amherst, NY, reviews in-process step in the manufacture of boron nitride. Blending zirconia with BN substantially increases its toughness.*

Chemical vapor infiltration is the most highly commercialized of the low-stress ceramic matrix composite processes.

in a joint venture with Lanxide Corp., Newark, DE, to develop directed metal oxidation (DMO) technology for fabricating fiber-reinforced CMCs.

In the DMO process, the matrix is grown by reacting a molten metal vapor with an oxidant. The metal is progressively drawn through its own oxidation product, resulting in a ceramic product.

"We use aluminum to make alumina or aluminum nitride, depending upon the reaction that takes place, or we use zirconium to make zirconium nitride or zirconium diboride," says Michael Hollins, a vice president at Lanxide. "Most ceramics tend to be the result of reactions between metals and some kind of reactant."

"We've worked with aluminum, zirconium, titanium, silver, hafnium, and tin," he says. "If there is a useful reaction product of a metal, there is a good probability our technology can be applied to a metal precursor to obtain a ceramic product."

The DMO process has been used to make 2-m-long heat exchanger tubes, rocket motor components, and wear- and corrosion-resistant components for the mining and chemical process industries.

Another low-stress process is being developed by researchers at NASA's Lewis Research Center. Here, a liquid Mo-Si alloy infiltration process, developed by Yet-Ming Chiang at Massachusetts Institute of Technology, Cambridge, is used to create an SiC-fiber-reinforced SiC matrix by infiltrating silicon into carbon preforms.

"The Mo-Si alloy converts the carbon to silicon carbide and the molybdenum shows up as molydisilicide in the pores of the preform," says Donald Behrendt, a research scientist at Lewis Research Center. "The Mo-Si eliminates any free silicon that might remain in the final material."

$MoSi_2$ also is the most oxidation-resistant material of all the silicides. Behrendt coats the SCS6 fibers in this CMC with BN to protect the fiber from the molten silicon.

NASA Lewis researchers also are working on a similar reaction process for forming a silicon nitride CMC matrix. In this process, the existing carbide coating on the SCS6 fiber can be used to protect the fiber.

continued

Tougher Testing for Toughened Ceramics

Some of the characteristics that make ceramics so useful—hardness, stiffness, and thermal stability—also complicate the testing of these materials. To prevent a stray bending load from distorting a test result, for example, researchers can take more than a week aligning a ceramic specimen in a conventional tensile test fixture. Additionally, most tests need to be run at high temperatures.

Creating a more fracture-resistant ceramic matrix composite (CMC) further complicates this testing. Fiber-reinforced CMCs, for example, don't follow predictable failure rules. Different failure modes often occur within the normal operating temperature range of a CMC.

Chemical changes in the composite at elevated temperatures, such as oxidation of SiC reinforcing fibers, add even more variables.

Bend tests have been the primary method for measuring the strength characteristics of ceramic materials because these tests are simple and cost effective. However, bend tests don't supply all the strength data you need to design a new product.

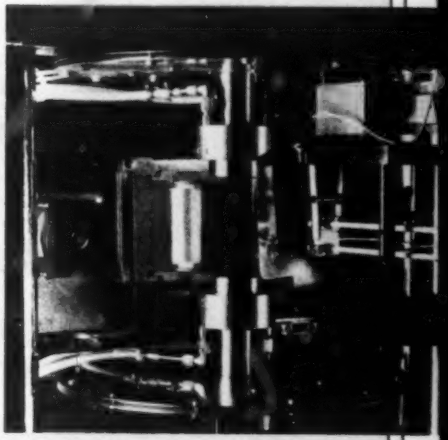
Self-aligning grip systems recently have been developed that eliminate bending loads in the more comprehensive tensile tests. These grips allow you to obtain more information on CMCs quickly, economically, and at temperature.

"We tensile test CMCs up to 1600 C and we have ideas that will allow us to test at 1800 C," says David Jablonski, manager of the research lab at Instron Corp., Canton, MA. "We have requests to test to 2300 C, but we have not done that yet."

The hardness and wear-resistance at temperature of CMC materials force yet more new test fixtures to be developed. Christopher DellaCorte and Serene Farmer, researchers at NASA Lewis Research Center, Cleveland, developed a special apparatus that measures the friction and wear behavior of a SiC-whisker-reinforced alumina at 1200 C. This information helps determine if CMCs can be used to make automotive engine cylinder liners.

Measuring the fracture toughness of CMCs is difficult and often confusing. No standardized method has yet been developed. The Vickers indenter method is the most widely used method because it's fast and inexpensive. It's also more acceptable than putting a notch in a notch-sensitive material.

In all these cases, electron microscopy of the failed CMC section is used to correlate the measured physical values with the actual reason for the ultimate failure. In monolithic ceramics you look for defects as the primary cause of failure. In CMC materials, you also look for problems in the reinforcement, the interfaces, and the reinforcement coatings.



High-temperature test system with capacitive extensometer, short furnace, and special grip system allows tensile test of ceramics without bending loads.

NASA Lewis Research Center technician loads a ceramic tensile test specimen in a sealed environmental test chamber.

'We licensed ceramic technology to solve the problems of scale up from lab to production,' says DuPont's Warren Hewett.

Another ceramic-toughening concept being developed is to laminate different ceramic materials. Researchers at Ceramatec created a three-layered composite consisting of 200-μm-thick monoclinic Al_2O_3-ZrO_2 outer layers encasing a tetragonal Al_2O_3-ZrO_2 core.

This process relies on the retention of surface compressive stresses in the skins to toughen the product. Under a load of 1,000 N, test samples had seven times the compressive strength of a comparable monolithic product.

"We're making three-layered cam followers for automotive applications," says Raymond Cutler, a scientist at Ceramatec. "However, manufacturers want this system to be cheaper than metal parts."

Researchers at the Center for Advanced Materials, Pennsylvania State Univ., University Park, also have fabricated laminated ceramic composites to improve fracture toughness. Maurice Amateau and Gary Messing found that a laminated SiC-whisker-reinforced alumina composite with high residual compressive stresses in the skin had more than twice the compressive strength of a comparable monolithic product.

Still another toughening method is being looked at by Waltraud Kriven, professor of materials science at Univ. of Illinois, Champaign. In this case, a material that undergoes phase transformations under stress, such as dicalcium silicate or a lanthanide sesquioxide, is added to the ceramic as a toughening agent.

"We allow the ceramic to crack in such a way that the crack uses up some of its energy in forming a particular type of basic crystal structure," says Kriven.

Zirconia parts with this additive had three times the toughness of nonreinforced zirconia parts. "The composite structure helps the zirconia keep its shape, confining the transforming explosions to pushing on the crack and closing it," she says.

Zirconia by itself also can be used as a toughening agent for other ceramic materials. Researchers at Carborundum, Niagara Falls, NY, added zirconia and SiC to toughen normally brittle boron nitride. The resulting glassy ceramic is stronger and more corrosion resistant than boron nitride, while retaining BN's high temperature and electrical performance.

Further refinements to these toughening processes and material developments should continue to drive down the overall cost of CMCs and create even more applications. **R&D**

O. Omatete (left) and Mark Janney, *researchers at Oak Ridge (TN) National Laboratory, demonstrate a gelcasting process they use to make ceramic rotors for gas turbines.*

READER RESPONSE PANEL

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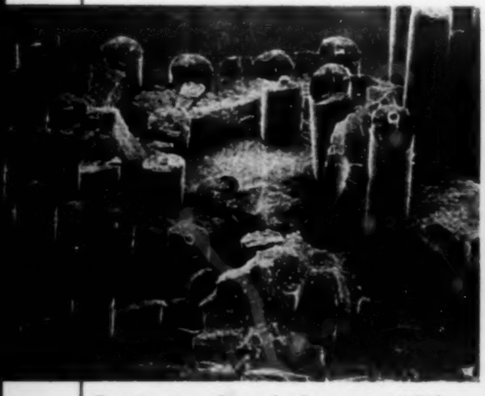
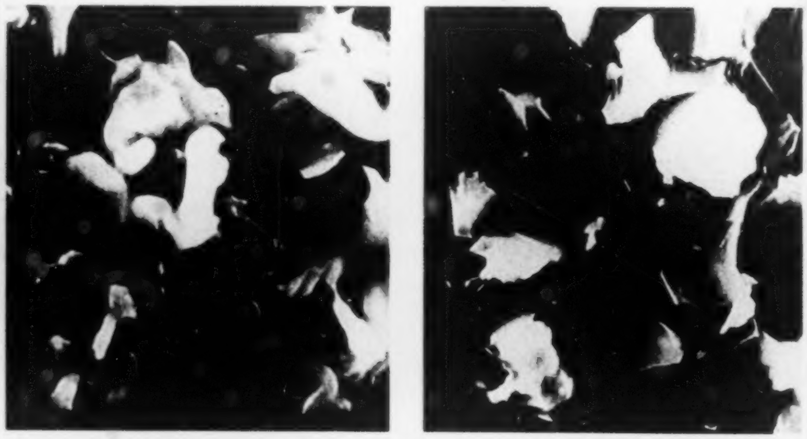


Fracture surface *of a hot-pressed SiC-fiber-reinforced celsian glass composite reveals the fiber pull out that toughens the brittle glass matrix.*



Fracture surface of porous carbon *(left) is compared with a similar fracture surface after being infiltrated with Mo-Si alloy (right) creating a SiC matrix with excess silicon.*

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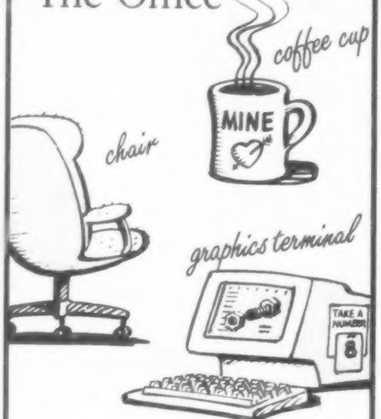
ABP BPA

Three Things You Shouldn't Have To Share At The Office



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ABOUT THE COVER Artificial intelligence systems learn much the same way humans do. *See article, page 36.*

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Based loosely on biological intelligence architectures, these artificial intelligence systems actually learn on the job.

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This year's Scientist of the Year joins the ranks of those who have made important contributions to science and technology.

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Remember to fill out the annual *R&D* Salary Survey on page 83. The more responses we get, the better the data. And the better the data, the easier it will be for you to argue for your next raise. Thank you.

R&D BUSINESS

Plastic Waste Needs Technical Answers

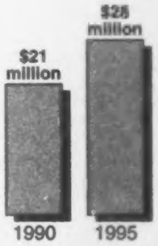
Current industrial solutions for handling plastic waste are not likely to be considered as sensible approaches to the problems of waste handling for very long, says Rodney Lowman, vice president for government affairs at the Council for Solid Waste Solutions, Washington, DC.

"Current solutions, such as mandatory recycling or product packaging bans, are expedient solutions to political problems at all levels of government," said Lowman in a speech at the recent National Plastics Exposition in Chicago. "The plastics industry needs to develop and implement long-lasting technical solutions (such as economic recycling and waste minimization) for its waste management problems.

"Plastic waste solutions, for the most part, don't require rocket science-type technical solutions," he says. "These are fundamental materials management problems which involve the challenges of obtaining the least environmental and economic costs to our society.

"Sensitive manufacturers are already feeling the pressure and are demanding products with ultimate disposal in mind," he says. ☐

Slow Growth for Rheometers



The market for torque rheometers will grow more than 6% annually through 1995 to $28 million, according to Strategic Directions Intl., a Los Angeles-based management consulting firm.

Rheometers are used primarily in the organic chemical, petrochemical, plastics, and pharmaceutical industries. Western Europe is the largest geographic region for rheometers, with 45% of the worldwide market.

States With Basics Are More Competitive

If your home state has not already invested in economic fundamentals, it is likely to suffer more during the current recession than states that did invest, and it will have less success in global trade than other states, according to a recent report, *The 1991 Development Report Card for the States*, published annually by the Corporation for Enterprise Development (CFED), Washington, DC.

A state's underlying development structure dictates how competitive it and companies within its boundaries will be, says Doug Ross, president of CFED. The report tabulates 23 economic indexes combined into four subindexes: human resources, technology resources, financial resources, and infrastructure.

Despite continual updates in these measures, state rankings do not change a whole lot from one year to the next. The results are largely unchanged, not because the indexes are insensitive, but because changes in a state's fundamentals take time. Economic investments are inherently long-term with slow payoffs.

This is often why states that seek highly visible short-term results, such as tax abatements, will experience long-term economic deterioration by postponing needed "invisible" improvements in infrastructure.

While many resources, such as technology, are critical to a state's economic growth, they alone cannot guarantee growth. States with strong technology assets, such as California, Massachusetts, and New York, have seen recent hard times. However, when the general economy turns around, these states, with their large pools of highly skilled technologists and strong R&D facilities, will be well positioned for future growth.

For a copy of the report: 202/408-9788. —*Tim Studt*

States Get Their Report Cards For Development Capacity

Rank	Human resources	Technology resources	Financial resources	Infra-structure
1 Minnesota	A	B	A	A
2 Washington	A	B	B	A
3 Utah	A	A	C	A
4 Massachusetts	B	A	A	C
5 Colorado	A	A	D	A
5 Connecticut	A	A	A	C
7 California	C	A	A	B
7 Delaware	C	A	B	A
9 Maryland	B	A	C	A
10 New Jersey	B	B	A	B
10 Pennsylvania	C	B	A	B

Source: Corporation for Enterprise Development

To assess development capacity, 23 measures, including R&D per capita, venture capital per capita, and utility costs, were combined to form the four subindexes shown.

Instrument Firms Help Find Funding

If your proposed research project entails buying new analytical equipment and you are involved in academic research, there are a few instrument makers that may be able to help you find a funding source.

GOW-MAC Instrument Co., Bridgewater, NJ, recently joined Spectra-Physics, San Jose, CA, and Nicolet, Greenbelt, MD, in offering free grant-assistance programs. Each com-

MODIL Integrates New Optics Technologies for SDI

Curt Maxey, an Oak Ridge (TN) National Laboratory engineer, operates a scanning Hartman device, which uses laser light to confirm the shape of diamond-turned optics to better than one-eighth wavelength.

This is one of several advanced devices installed at ORNL's Optics MODIL (Manufacturing Operations Development and Integration Laboratory). MODIL helps the U.S. optics industry increase its precision engineering capabilities by searching globally for new manufacturing technologies that could be used to produce advanced optical components for the Strategic Defense Initiative (SDI) program.

Ion Beam Focused To 8-nm Width

Focused ion beam (FIB) lithography is becoming an increasingly attractive way to achieve sub-100-nm feature sizes on advanced high-speed optical and electrical devices, because FIB widths are continuing to shrink. Randy Kubena and his associates at Hughes Research Labs, Malibu, CA, recently attained an FIB that's only 8 nm in dia, which is believed to be the smallest ion beam to date.

The team used a two-lens microprobe system and a single-isotope gallium ion source. The 50-keV system is essentially the same as that used at Hughes four years ago to achieve the previous ion beam record of 15 nm, which produced distinct lines as small as 12 nm in a thin layer of polymethyl methacrylate (PMMA) resist. The new 8-nm beam produces features as small as 6 to 8 nm.

The FIB's optical system was changed a bit to net the latest advance, Kubena says. "Essentially we ran the system with lower magnification. We decreased the object distance of the first lens and refocused the beam. Doing this decreased the chromatic aberration of the whole system, which let us reduce the spot size."

Monte Carlo calculations predicted that we should see energy broadening effects at a gallium ion exposure somewhere below 40 nm, Kubena says. "It was predicted that the effects might cause limits in the 20- to 40-nm range, and it was a little surprising that we could get down to the 10-nm range before we began encountering them."

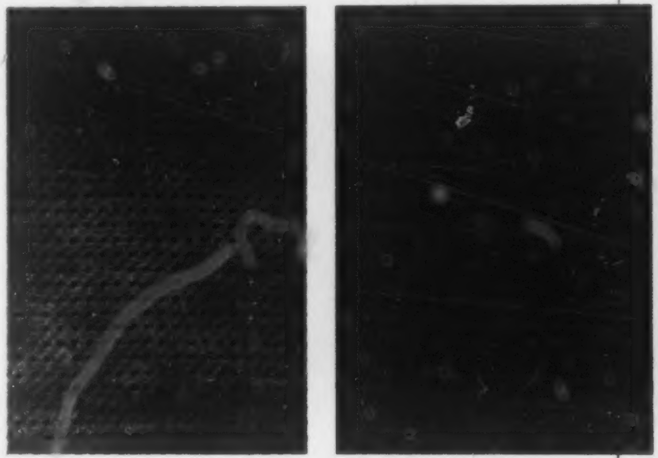
Both dots and lines were made, and it was found that dot size varied greatly. "Because we were dealing with such small regions and were putting in a very few ions (under 20 ions/pixel), we were getting a large variation in dot sizes. With lines, which were made by laying down a series of dots very close together, there was less sensitivity, but still effects were seen.

"This indicates the need to develop a less sensitive resist for very small exposures of both dots and lines," Kubena says. Kubena's group is working on finding alternatives to PMMA, but details are proprietary at the moment.

Fabricating devices down to nanoscale dimensions calls for new approaches to facility design. For good results, not only is a cleanroom needed, but also a noise-free room.

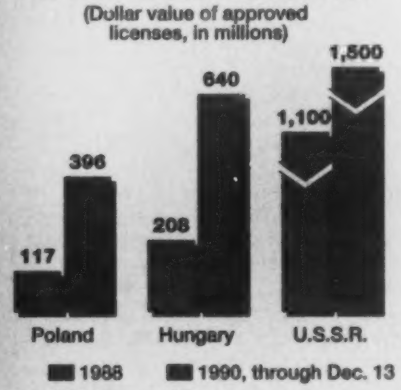
"Any extraneous noise such as air conditioners or background noise in general can affect beam size. All of that must be addressed in utilizing these concepts," Kubena says. ☐

News continues



Dot arrays produced in a 60-nm-thick PMMA resist by an 8-nm-dia Ga^+ FIB. Dot size at right is from 10 to 20 nm.

U.S. High-Tech Exports Rise As Iron Curtain Crumbles



Source: U.S. Commerce Dept.

A dramatic increase in licenses for sales of technological goods to Eastern Europe by U.S. companies was due to political and economic changes inside the former East Bloc countries combined with an easing of U.S. export restrictions. Included are computers, machine tools, and aerospace products.

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R&D BUSINESS

Instrument Needs for Academics Revealed

More researchers in academic institutions buy new analytical instruments to study emerging technologies than to replace obsolete or nonfunctional equipment, according to a recent U.S. National Science Foundation (NSF) study.

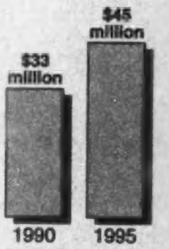
For all of the science and engineering fields surveyed, 58% of the purchased instruments were needed for experiments that could not be performed with existing equipment. Replacement needs accounted for 17% of the instrument purchases, and expansion of existing capabilities accounted for the remaining 25%.

More than $800 million in equipment purchases were made during the 1988 to 1989 academic year. After adjusting for inflation, this is an 11% increase over purchases in 1985 to 1986. Average instrument prices during this period rose slightly, except for some types of bioanalytical equipment which had substantial increases.

An NSF study for the 1983 to 1984 school year reported that 72% of academic department heads said that their faculty researchers could not perform critical experiments because they lacked the necessary equipment. The current 1989 to 1990 survey asked the same question and found that, while still relatively high, this limitation had been reduced to 62%.

For a copy of this free report *Academic Research Equipment and Equipment Needs in Selected Science and Engineering Fields: 1989-1990* (NSF 91-311), call 202/357-7492. ☐

Particle Analyzers Lead the Pack



Sales of particle size analyzers used in analytical laboratories are expected to grow 6.4% annually over the next five years to $45 million in 1995, according to Strategic Directions Intl., a Los Angeles-based management consulting firm.

These sales will outpace those of other physical property measurement instruments, such as surface area analyzers, zeta potential analyzers, and porosimeters.

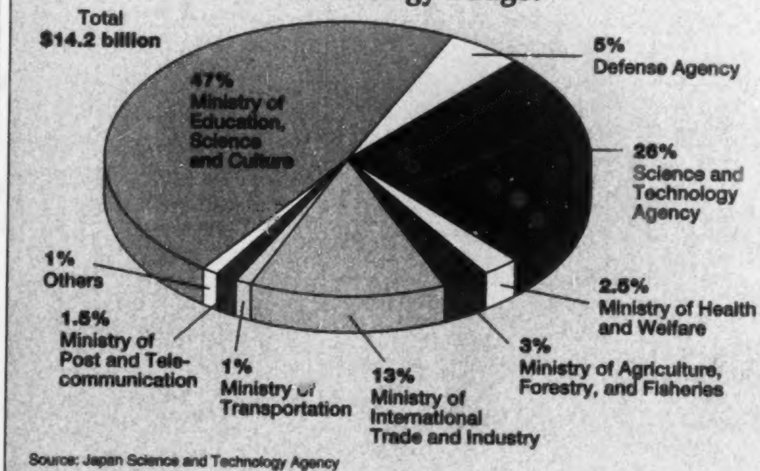
Japan Continues Its Heavy R&D Investment

No matter which sector of the Japanese community you look at, you will find continued evidence of recent increases in its R&D spending. A survey by Japan's National Institute of Science and Technology Policy reveals that R&D expenditures by Japan's top 10 companies in sales in FY89 were 8.3% larger than even their spending on manufacturing plants and equipment.

Another survey of 16,200 businesses, universities, and private institutions by Japan's Management and Coordination Agency reveals that total R&D expenditures rose 11.2% in FY89. U.S. R&D in FY89 rose only 5%, according to the U.S. National Science Foundation. Japan's Science and Technology Agency also increased its budget 6% in FY90 with large increases to nuclear energy facilities.

Estimates of current trends indicate that U.S. and Japan R&D spending increases may be changing (see *R&D* August 1991 Business). ☐

How Japan Distributes Its Science & Technology Budget



Source: Japan Science and Technology Agency

***Japan's science and technology budget** promotes R&D in nuclear energy and safety, space development, earth and ocean sciences, materials, and life sciences.*

Stay Competitive By Integrating R&D

Concurrent engineering (CE) is the latest buzzword for integrating a company's overall resources to produce new products faster, with higher quality, and at a lower cost. It's really a combination of many new manufacturing concepts, such as just-in-time scheduling, total quality management, and design-for-manufacture concepts.

"A 10% evolutionary improvement in your manufacturing response time is no longer adequate to be competitive," says Sammy Shina, associate professor of engineering at the Univ. of Lowell, MA. "Companies that use the combined capabilities of CE are able to implement improvements by significant orders of magnitude."

Late delivery of a new product, for example, often is the biggest cause for loss in a company's profits, according to Shina. "The iterative nature of conventional product development cycles is mostly to blame for these late deliveries," he says. "The most important result of applying CE is the shortening of a product's concept, design, and development process by changing it from a serial process to a parallel one."

Shina is author of *Concurrent Engineering and Design for Manufacture of Electronic Products,* published by Van Nostrand Reinhold. ☐

Equipment Sourcing Follows Production

As semiconductor component production shifted from U.S.-based companies to Asian companies over the past five years, so did the sourcing of equipment to manufacture these products, according to a recent survey by VLSI Research Inc., San Jose, CA.

The market for semiconductor manufacturing equipment grew by 80% during this period, from $5.1 billion in 1985 to $9.3 billion in 1990.

In 1985, seven of the top 10 semiconductor equipment manufacturers were U.S.-based companies and only two were Japanese. In 1990, the leader board had changed with Japanese-based Tokyo Electron Ltd., Nikon, Advantest, Canon, and Hitachi dominating the top spots.

Only Santa Clara, CA-based Applied Materials has increased its share and moved from the tenth spot in 1985 to the third in 1990. ☐

1990's Top 10 IC Equipment Firms

		Sales (millions)
1	Tokyo Electron (Japan)	$706
2	Nikon (Japan)	692
3	Applied Materials (U.S.)	572
4	Advantest (Japan)	423
5	Canon (Japan)	421
6	Hitachi (Japan)	304
7	General Signal (U.S.)	286
8	Varian (U.S.)	285
9	Teradyne (U.S.)	218
10	SVG (U.S.)	204

Source: VLSI Research Inc.

Japanese firms dominate a list of the top semiconductors equipment makers.

Is East Europe A Research Bargain?

Since the end of the cold war, East European countries have received a lot of scrutiny in an effort to commercialize their untapped technological capabilities.

Czechoslovakia, Hungary, and Poland are considered to be the strongest contenders for technical ventures, according to Ernest Gilmont, a senior consultant at Arthur D. Little Inc., Cambridge, MA. "Few Westerners realize what a strong work ethic and engineering skill base Czechoslovakia has," says Gilmont.

However, Hungary still is the most attractive partner for Western companies, because it started the partnering process several years ago.

While East European countries have a lower standard of living than that of Western countries, their technologies often are similar, says Gilmont.

"This window of opportunity may not be open for long," says Gordon Feller, a staff member at the International Technology Institute, Pittsburgh. "As Eastern researchers secure intellectual property rights over their work, they will become tougher business partners." **R&D**

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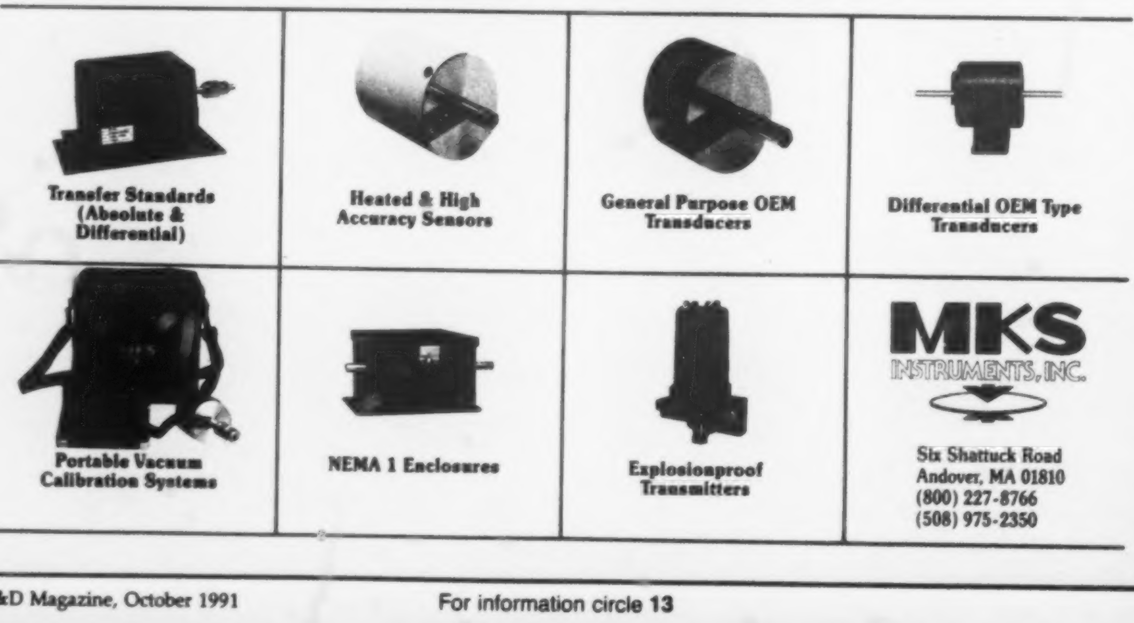
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